SUPPLEMENT

TO THE

32ND ANNUAL REPORT OF THE DEPARTMENT OF MARINE AND FISHERIES, FISHERIES BRANCH

CONTRIBUTIONS

TO

CANADIAN BIOLOGY

BEING STUDIES FROM THE

MARINE BIOLOGICAL STATION OF CANADA

1901

BOARD OF MANAGEMENT :

OTTAWA
PRINTED BY S. E. DAWSON, PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
1901

PREFATORY NOTE

BY THE DIRECTOR.

In the series of papers here presented, the notes embodied in the first paper deal with certain salient features in the history and work of the Marine Biological Station of Canada, founded in 1898, under authority of an Order in Council dated the 9th of May of that year, and it is necessary only to mention in this place that during the first two years of its existence the Station was located in Passamaquoddy Bay near St. Andrews, New Brunswick, and that it was moved in the third year to the Straits of Canso near the town of Canso, Nova Scotia. Part of the work done by the Staff during the stay at St. Andrews is embodied in the papers now published.

E. E. P.

OTTAWA, 1901.

CONTENTS.

PLATES.

I

MARINE BIOLOGICAL STATION OF CANADA.

INTRODUCTORY NOTES ON ITS FOUNDATION, AIMS AND WORK, BY THE DIRECTOR (PROFESSOR E. E. PRINCE.)

The founding of the Canadian Marine Biological Station under Government auspices three years ago, may be said, without exaggeration, to mark an era in the progress of science and technical research in the Dominion.

Two primary objects were kept prominently in view by those who initiated the project, viz. :—The advancement of the fisheries of the country and the interests of the fishing population resident along our shores, as well as the enlargement of existing knowledge on marine fishes and other living organisms in the waters of the Gulf of St. Lawrence and along the Atlantic coast of Canada.

Marine investigations, it must be remembered, have been carried on in our waters by Canadian and foreign workers for nearly seventy years; but the results of the work accomplished by scientific men, including such authorities as the late Sir William Dawson, Dr. J. F. Whiteaves, Professor Ganong, and certain eminent United States biologists, had a far less direct bearing upon the fisheries and fishing industries than would have been the case had a scientific school or Marine Biological Station existed upon our shores. Other countries long ago realized this, and founded and equipped such stations, where biologists have had every facility for attacking the pressing and difficult problems of the deep-sea and inshore fisheries.

During my first maritime tour as Dominion Commissioner of Fisheries, I was impressed not only with the desirability of some thorough and systematic investigation into fish life, and marine life generally, in Canadian waters, but also with the absolute necessity for a laboratory, where exhaustive researches could be carried on, and adequate solutions attained in regard to questions vitally affecting the fisheries, and I ventured to point out in my first formal report, dated October 5, 1893, addressed to the Minister of Marine and Fisheries, at the time, (Sir C. H. Tupper) how urgently these matters called for attention. I laid stress on the scattered and limited amount of knowledge we possessed on such subjects as the spawning periods and breeding areas of valuable food-fishes, and the great loss of valuable fishery resources resulting annually, especially by non-utilization and waste, and I called attention to the urgency of preventing this waste of valuable fish-products, and of thus stimulating new fishery enterprises. The Minister was forcibly impressed by some of the points I stated, and he requested me to fully report as to the best means of accomplishing a systematic fisheries' survey, of improving the fishing industries, and of creating the new enterprises to which I referred. Accordingly, in 1894, I prepared a special report, published in the Annual Report of the Department of Marine and Fisheries, entitled: 'A Marine Scientific Station for Canada,' and I laid stress on the growing interest being taken by the public in this country and in other countries in biological investigations upon the conditions of life in the sea. Further, I drew special attention to the peculiar richness, variety and value of the Canadian fishing grounds as a field for investigation. I alluded to work carried on in the British

Islands and in certain foreign countries, and emphasized the importance and rare interest of the results of dredging and collecting expeditions which had been carried on in Dominion waters by the Canadian biological workers already referred to, and I added : 'The fact that year after year professors and bands of students from the United States 'resort to Canadian shores to carry on marine studies, preferring our prolific waters to 'their own, clearly proves, if proof were needed, that a Marine Station in Canada would 'be able to accomplish great results.'

Sir William Dawson, in his earlier days, as early indeed as 1835, made collections of marine invertebrates in his native county of Pictou, and in 1858, completed successful dredgings in the Gulf of St. Lawrence, off Gaspé. In 1859, and in later years, he carried on dredging work in the entrance to the St. Lawrence, as far up as Murray Bay, and continued this work off Little Metis from 1876 to 1882. Dr. Robert Bell, in 1858 made a collection of invertebrates over much the same grounds, and two United States workers, Dr. J. R. Willis and Dr. W. Stimpson, the former from 1850 onwards, and the latter in 1852, conducted important dredging expeditions in Nova Scotia and New Brunswick, the published reports of which are well known and justly regarded as of great value. Dr. Stimpson's 'Marine Invertebrates of Grand Manan,' published in 1853, has long been a classic book of reference. Moreover, Dr. A. S. Packard, and Professor Verrill also made important collections, especially in the Gulf of St. Lawrence, under the auspices of the United States Fish Commission. The later investigations included the waters of the Bay of Fundy, a faunistic region differing in a marked degree from the waters of the Gulf of St. Lawrence.

In many respects, the most important Canadian work carried on by a marine biologist, was that of Dr. J. F. Whiteaves, who from 1867 to 1873, collected marine forms, and published lists of mollusks, etc., of permanent value, and a very special interest attaches to Dr. Whiteaves' work, inasmuch as in 1871, 1872 and 1873, the Department of Marine and Fisheries afforded facilities to this distinguished scientist, to carry on dredging expeditions in the deep waters of the Gulf of St Lawrence from Anticosti to Cape Breton. The results of this work are of unusual utility and importance, and were published in the Department's reports in the three years 1871–1873. They embrace many valuable observations directly bearing upon the deep-sea and inshore fisheries.

The famous *Challenger* expedition in 1873 touched the coast of Nova Scotia; but the work done was somewhat brief and fragmentary, though of considerable scientific interest.

Mention should be made of the valuable and extensive reports on the Bay of Fundy fisheries by Dr. Moses H. Perley, of St. John, N.B., accompanied by reports on the fishes of New Brunswick and Nova Scotia, published originally as appendices to the Journal of the New Brunswick House of Assembly, Fredericton, N.B., in 1851. About the same date Dr. H. R. Storer published his 'Observations on the fishes of Nova Scotia and Labrador.' Mr. T. F. Knight, under the auspices of the Nova Scotia Government, prepared similar reports and lists of fishes, edible mollusks, &c., which were published in 1866 and 1867. Dr. J. B. Gilpin of Halifax, N.S., Dr. Abraham Gesner of Annapolis, N.S, the Rev. John Ambrose, St. Margaret's Bay, N.S., and others also published twenty or thirty years ago interesting papers on the fish and fishing industries of Nova Scotia and New Brunswick. Of these minor zoological publications, it is not necessary to say much, except to point out that Professor W. F. Ganong dredged in the southern waters of the Bay of Fundy, and published valued lists of mollusks and other invertebrates comparable in many ways to those issued by various well known United States scientific workers during the last twenty years.

The suggestion which I had made in 1894, that marine investigations could not yield adequate results and could be of only limited national benefit unless some properly equipped station existed on our shores, was taken up by Professor Knight of Queen's University, Kingston, who, on May 6, 1895, addressed a letter to the Secretary of the Royal Society of Canada, Sir John Bourinot, on the subject. This letter was published in the Proceedings of the Royal Society, and it urged the desirability of a lake or seaside laboratory in Canada, to which our own naturalists could resort for some months every summer and pursue research work in biology. Dr. Knight referred to

the presence of no less than seven Canadian scientific men working at the U.S. Marine Biological Laboratory at Wood's Hole, Massachusetts, and he concluded by affirming that 'Canada ought to make a beginning, and afford opportunities within the borders of the Dominion for scientific specialists to gratify the honourable ambition of adding a little to the sum of human knowledge.' The Royal Society discussed the matter in Section IV. (Geological and Biological Sciences), at its meeting in 1895, and a scheme rapidly took practical shape on the recommendation of a committee, appointed by the British Association in 1896. This committee, which was really a committee of Section D (Zoology), was appointed to consider the question of investigating the marine fauna of the Atlantic waters of Canada, by means of a Marine Station. The members held a sitting in Toronto, on the occasion of the meeting of the British Association in that city, in 1897, the chairman being Professor Louis C. Miall, President of Section D, and the committee concluded its labours by recommending the appointment of a Canadian committee, with myself as chairman, and Professor D. P. Penhallow as secretary, and the recommendation was signed by Mr. W. E. Hoyle, as one of the secretaries of the Section, and was in the usual way communicated to the General Secretary of the Association, so that final steps could be taken to carry it out. In October, 1897, Mr. G. Griffith wrote to me an official notification that the Biological Station committee referred to, embraced the following gentlemen: Professor John Macoun, Professor T. Wesley Mills, Professor E. W. MacBride, Professor A. B. Macallum, Mr. W. T. Thistleton-Dyer, (Director of the Royal Gardens, Kew), Professor D. P. Penhallow as secretary, and myself as chairman. This committee at its meeting in Montreal decided upon bringing the project before the Dominion Government during the session of 1898. A memorial was prepared, addressed to the Hon. the Minister of Marine and Fisheries, pointing out that the committee's appointment had been recommended at the meeting of the British Association for the Advancement of Science, by the Sections of Zoology, Botany and Physiology, and it called attention to the great importance of our fishing industries and the inadequacy of our knowledge respecting the nature and source of the food supply of fishes, and of oysters, lobsters, &c., and it urged that suitable measures be adopted for the scientific investigation of such questions, as well as for the more critical study of the life-histories of important marine organisms used for food. Amongst other things, it was pointed out that it was desirable that the station commence its work at some appropriate point in the Maritime Provinces, and that it be moved to new locations, according to requirements. In its representations to the Minister it concluded as follows:—

That the various universities and scientific bodies of Canada should be granted certain privileges with respect to opportunities for qualified investigators, as may hereafter be determined.

That the scientific work of the station be executed as far as possible by experienced investigators connected with our various universities.

That while the station remains a Government institution, the administration be vested in a special board consisting of one or more representatives from the Department of Marine and Fisheries, and one representative from each of the universities represented in the delegation.

That an appropriation of $15,000 be made for the purpose, of which $5,000 shall be applied to construction and outfit, and $10,000 to maintenance for a period of five years.

In support of which petition the committee announced the co-operation through their delegates, of Toronto University (Prof. Ramsay Wright), Queen's University (Sir Sandford Fleming), Laval University (Mgr. Laflamme), McGill University (Prof. D. P. Penhallow and Prof. E. W. MacBride), Dalhousie University (Prof. B. Russell, M.P.), The Royal Society of Canada (Prof. D. P. Penhallow), Nova Scotia Institute of Science (Professor Benjamin Russell), The Canadian Institute (Prof. A. B. Macallum), Natural History Society of Montreal (Dr. F. D. Adams), and the Natural History Society of New Brunswick (Prof. Bailey).

On Wednesday, April 20, 1898, a deputation waited upon the Hon. Sir Louis H. Davies, Minister of Marine and Fisheries, in Ottawa to present the memorial. The accompanying deputation was a large and influential one, and included the Hon. Dr. Borden, Sir Sandford Fleming, Dr. Roddick, M.P., Dr. Russell, M.P., Mr. (now Senator)

Ellis, Mr. E. Goff Penny, M.P., Professors F. D. Adams, D. P. Penhallow, A. B. Macallum, E. W. MacBride, John Macoun, and Edward E. Prince. The committee appointed by the British Association presented the petition to the Hon. the Minister, supporting it by remarks emphasizing the more salient points. A very strong case was made out in the speeches of the various members of the deputation in favour of a Government Biological Station, and at the conclusion of the interview, Sir Louis Davies expressed his pleasure and gratification at meeting the deputation, and having had presented to him the information regarding marine and fisheries investigations which had been given by the various speakers. As a result the sum of $15,000.00 was placed in the estimates and passed by Parliament, $5,000.00 being for the building and equipment, and a sum of $2,000.00 to be paid annually for the five years 1898–99 to 1903–04 to carry on the scientific work of the station.

Reference may here be appropriately made to some of the more important considerations urged by the delegation. The immense value and importance of the Canadian fishing interests were adverted to, and stress was laid upon the inadequacy of existing knowledge with respect to the nature and sources of the sustenance of marketable fishes and of oysters, lobsters, &c., as well as the distribution, migrations and natural history of marine animals in Canadian waters. The necessity of exact scientific investigations into such questions was urged, and it was shown that Canada was the only civilized country in which no Marine Biological Station had been established. Great benefit would be derived by the Government, it was pointed out, from co-operation with the different universities and scientific bodies in the Dominion in its administration of fishing interests and in deciding upon methods of fish-preservation by the utilization of reliable technical information obtained by means of such a Biological Station. The Station would prove of incalculable service to our universities, not only in furnishing them material in Canada which has now to be obtained largely from foreign sources, but in adding to the material thus obtained, accurate scientific knowledge of fishes and of the marine life generally which characterizes our northern waters, and differs from the marine fauna and flora found in the vicinity of the Biological Stations now at work on the shores of the United States. The results obtained by a Canadian station could be compared with corresponding results in the waters off the British Islands, where valuable biological investigations have been conducted for a considerable period. Mutual benefits would, it was anticipated, result which would be of value to the Imperial authorities and the Universities of Britain as well as to our own Government and the Universities of the Dominion. Finally the delegation suggested that if Government aid were granted, the responsibility for the administration of the Station might appropriately be assumed by the committee appointed by the various Universities and Scientific Institutions, with a representative from the Department of Marine and Fisheries.

The representative committee referred to, which is responsible for all arrangements and expenditures and the administration of the work of the Biological Station, includes delegates from all the principal seats of learning in the Dominion.

The Canadian committee appointed by the British Association met in March in the Botanical laboratory of McGill University, Montreal, at the kind suggestion of Professor Penhallow, and the details of the scheme were discussed, the main features of the Station and its proposed work decided upon, and a Board of Management being appointed, consisting of :—Professor D. P. Penhallow, McGill University, Montreal, Secretary ; Professor R. Ramsay Wright, Toronto University, Toronto ; Professor L. H. Bailey, University, Fredericton, N.B. ; Professor A. P. Knight, Queen's University, Kingston, Ontario ; Reverend V. A. Huard, Laval University, Chicoutimi, P.Q. ; Dr. A. H. MacKay, Dalhousie University, Superintendent of Education, Halifax, N.S.

I, as Dominion Commissioner of Fisheries, was chosen as Director of the Station, and the names of Professor A. B. Macallum, Toronto University, and Professor E. W. MacBride, McGill University, were subsequently added to the Board.

After finally reporting to the British Association at its meeting in Bristol, in 1898, upon the successful issue of its work and the selection of the Board of Management, the committee dissolved.

This year (1901) Professor Ramsay Wright was chosen as Assistant Director in order to further facilitate the operations of the Station.

At the first meeting of the Board of Management, on February 10, 1898, in Ottawa, plans and specifications were considered, and it was arranged that tenders should be advertised for by the agent of the Department of Marine and Fisheries, at St. John, New Brunswick, and the location was fixed at St. Andrews, New Brunswick, on the shore adjacent to Indian Point, and near low-water mark. The successful tenderers were Messrs. D. W. Clark & Son, St. John, New Brunswick, and the nature of the building was to be such as to combine the advantages of a floating and movable, as well as of a fixed or more permanent institution.

A fixed location on land while advantageous for microscopical, physical, and minute chemical investigations on account of the absence of vibration, has the disadvantage of affording direct and convenient access to a portion of the coast only, viz., that portion of the coast in the immediate vicinity of the building. A floating station, on the other hand, has the advantage of ensuring the readiest opportunities of scientific investigation during the same season, or during successive seasons, along different portions of the coast and the waters adjacent thereto. As Mr. Richard Rathbun, a distinguished United States biologist, says, with reference to the marine investigations of the United States Fish Commission, 'many problems require to be investigated in particular localities, where 'the conditions are especially favourable. For that reason, the study of the habits and 'development of such forms as the oyster, the shad, the salmon, the Spanish mackerel, 'and many other species, have been conducted elsewhere' than at the permanent Woods Hole Marine Station. Mr. Rathbun further points out, in regard to permanent, fixed laboratories, that while they are indispensable to the study of fisheries' problems, they cannot, unless supplemented by convenient means for reaching distant points, be of more than local value and utility. It was the lack of such facilities, Mr. Rathbun goes on to say, during the first ten years of the Commission with which he was officially connected, that made it necessary to move its summer station from place to place.

The Canadian station was designed in the form of an ark or oblong building placed upon a large scow, so that it could be moved from one point to another along the coast, as the Board of Management might determine. At each chosen location it might be either moored or hauled up on dry land above high water mark, thus fulfilling the conditions of a floating as well as of a fixed scientific station. The building, during the first two years, was not placed upon the scow; but was erected on the shore at St. Andrews, New Brunswick, with the intention of having it placed upon the special scow whenever the Board of Management decided to move it away to a new locality. The laboratory was completed in June, 1899, and is a neat one-story structure of wood, well lighted from the roof and sides, and somewhat resembling a Pullman car, with a row of eight large windows along each side, and a door with sash provided with plate glass at either end. Its total length is 50 feet, the principal room, or main laboratory, occupying the central part of the structure and forming a well-lighted and cheerful work-room, measuring 30 feet in length, and 15 feet in breadth. Two tank- and store-rooms are at the anterior end, each room 6 feet by 6 feet, while at the opposite end are four rooms, one reserved for the director, another adjacent to the director's, devoted to the use of the attendant, and provided with a sink and spacious shelving, and certain kitchen appliances, while on the opposite side of the passage, are two rooms, one used as a tank room and the other as a chemical room, the last being provided with a table for chemical balances and other instruments, and with shelves for storing chemicals and re-agents. Of the eight windows on each side, half of them light up the main work-room. On the roof, which is slightly elevated in the centre, is a neat ventilator raised or skylight with nine movable panes on either side to admit light and fresh air. The scow on which the laboratory was placed in the spring of 1901, is 60 feet in length and 19½ feet in breadth, and about 9 feet from deck to the outside of the bottom planking, that is, in vertical depth. It provides a narrow platform around the sides of the building, and a spacious platform at each end 6½ feet in width. A small double-acting brass deck pump placed on the platform at the front entrance is connected by hose-pipe with the fresh-water

tank, and supplies the porcelain wash basins, one of which is provided at each worker's table. Near the location selected, at some little distance from the station, and adjacent to the seashore, a salt-water pump, with a Rider hot-air engine, 6 inch cylinder, and pump, are placed, and is connected by a pipe with a spacious salt-water tank on the roof of the building at the anterior end. From this tank a delivery tube, 1 inch in diameter, of galvanized iron passes close to the skylight into the interior of the station immediately under the horizontal cross-beams of the roof, giving off lateral branch tubes, five on each side, and supplying the salt water by special nozzles to the respective porcelain basins used by each worker. From this delivery tube temporary tanks can be supplied as required, and the final outflow empties into the salt-water tank in the tank-room next to the chemical room, at the rear end of the station. Along each side of the laboratory, under the workers' tables, a convenient drain carries away waste water, and has its exit beneath the laboratory. The station possesses a gasoline launch, 22 feet long, fitted with a Sintz engine, intended to be used for conveying the workers conveniently to points within easy reach. It was originally planned that this launch, which is 2½ h.p., should be utilized for bottom dredging, and for surface or mid-water townetting with capacious plankton and other nets ; but it has proved to be not well adapted for that work, on account of its insufficient power. A handy little row-boat was also purchased for the use of the staff. The equipment of the station includes a number of dredges of various sizes, a drag-seine 60 feet long, two large triangular nets after the Scottish model designed by Professor McIntosh, a beam-trawl, 15 feet across, and a number of fine silk and cheese-cloth tow-nets and dip-nets. In addition to a number of Agassiz store tanks, a series of copper store-tanks of various sizes have been procured.

While there is of course much to be added to the equipment, many of the workers have expressed themselves as well pleased with the provision in the way of nets and other necessary apparatus : but the desirability of the purchase of a tug or launch of some power, for deep-sea dredging, has pressed itself upon the attention of the staff. It is to be hoped that at an early date a suitable vessel will be secured.

Of course the complete equipment of a scientific marine station, the first of its kind in British North America, is a matter of time. Fittings and apparatus must of necessity be added as growing needs require. The most famous and splendidly equipped stations in the world have become such only after the lapse of many years. As Professor Stephen A. Forbes, Director of the Illinois State Laboratory on the River Illinois, remarked in his first report (1893–94) :—'It will be seen that our season's work has fully opened up the field, and shown us what is necessary to the continuance and development of our enterprise. I am entirely satisfied with the locality, and wish to occupy it next year in a more permanent manner, with a view to continuous work there for several years, probably no less than five. The present arrangements, while fairly satisfactory for this preliminary year and clearly the best that could have been made, were very inconvenient in some respects, and wasteful of the time and strength of the Station force.'

Every institution of this kind has had a similar experience and it must be a matter of sincere congratulation that the Canadian Biological Station, during the first three seasons of its existence, has been able to accomplish a large amount of useful and valuable work,and, in the scientific reports which follow these remarks, is able to present an instalment of results of a permanent character.

The Station possesses the nucleus of a library, including the fifty magnificent volumes of the report of the voyage of H.M.S. *Challenger*, a munificent gift, obtained through the kind offices of the Right Honourable Lord Strathcona, from the British Government, with the special approval of the Right Honourable Joseph Chamberlain, His Majesty's Principal Secretary of State for the Colonies. As a large number of important works are at this very time being added to the library, further remarks upon this subject will be reserved for a future occasion ; but it must be admitted that the members of the staff have been considerably hampered through lack of a good working library, furnished with the most recent memoirs and treatises, and in a great many cases the workers have had to borrow from University libraries and other sources, the standard

works necessary to assist them in their researches. This deficiency will, however, be rapidly overcome, and the Station will in due time possess a fairly satisfactory reference library.

The opinion was frequently expressed upon the founding of the Marine Station, that scientific workers would find it difficult, on account of the great distances and the necessary expense involved, in making use of the Station; but this fear has happily proved groundless, and the tables of the Station, during the three first seasons of its work, have been practically fully occupied. During the initial season on the opening of the Station the staff included Dr. R. R. Bensley, Demonstrator and Lecturer on Zoology in the University of Toronto; Mr. B. A. Bensley, a Fellow in Biology in the same University; Dr. Joseph Stafford, formerly Lecturer on Zoology in Toronto University, and now a member of the staff of McGill University, Montreal. These were the first scientific men to occupy tables and conduct investigations in the Station. Professor A. P. Knight, of Queen's University, Kingston; Professor A. B. Macallum, of Toronto University; Dr. F. S. Jackson, of McGill University; and myself, also spent some time at work during the season of 1899. Professor Penhallow, Professor MacBride, Professor John Macoun and Dr. A. H. MacKay had all intended spending some weeks at the Station carrying on scientific work, but were prevented, and these gentlemen wrote to me expressing regret at their inability to carry out their intention. Professor L. W. Bailey, University of Fredericton, N.B., and Miss Ganong, and Mr. F. T. Bower, of the staff of Queen's College, Kingston, attended, but had not opportunity to carry on much systematic work.

The subjects taken up during the first season were largely faunistic; but they also included a study of the food of fishes, and an investigation into the sardine fishery, and the catches of fish in the sardine weirs, a survey of the clam fishery, as well as an examination of the spawn of various marine fishes taken in the tow-nets; a study of some of the early stages in the life history of the lobster, and a research in physiological chemistry, dealing with the analysis of the constituent matters in Aurelia and in Medusæ generally.

During the season of 1900, the staff was augmented and included the following: Professor Knight, Queen's University, Kingston; Professor Macallum, Toronto University; Professor Fowler, Queen's University, Kingston; Dr. Joseph Stafford, Toronto University; Dr. F. H. Scott, Toronto University; Dr. F. Slater Jackson, McGill University, Dr. A. H. MacKay, Superintendent of Education, Halifax, and myself. Researches more or less extended were carried on from June until October 1. Professor MacBride, of McGill University, and Professor Bailey, of Fredericton, spent a few days at the laboratory, and the work during the season included a study of water-pollutions in relation to fish life; the food of sea urchins; the parasites of fishes; the blood of the lobster; the nerves of fishes; cell studies, especially in regard to Marine Protozoa; the chemistry and physiology of jelly-fishes, a study of the early stages of Atlantic and Pacific salmon, an examination of the local fauna, and a systematic survey of the flora of the adjacent district. These, and certain morphological subjects, covered the work completed at the station during the second year of its existence, and some results have already been sufficiently advanced to enable them to be placed in the form of the preliminary reports presented in the succeeding pages of this publication.

It is to be sincerely hoped that the contributions to Canadian Marine Biology, due to the founding of a Dominion Biological Station on our Atlantic shores, of which the present publication constitutes the first instalment, may grow in succeeding years in extent and value.

The aims of the station could hardly be more comprehensive, for they embrace the thorough investigation of plant and animal life in our eastern seas. The conditions attached to work carried on within its walls could not be more liberal and free, for such work is trammelled only by the condition that the results shall add to the knowledge of our national resources in the deep, and shall more or less directly benefit our fisheries. The bearing of such scientific researches were well expressed by the late Hon. Marshall McDonald, United States Commissioner of Fisheries, when he said:—'The knowledge to be obtained by such investigations is absolutely necessary as a foundation upon which

to build an intelligent, rational administration of our fishery interests. A knowledge of life in its relation to environment is an important subject which biological investigators have not heretofore sufficiently dealt with, but which, it seems to me, is necessary in order to give practical value to special studies of the different species. After all, it is the relations and interdependence of life in the aggregate, and of the conditions influencing it adversely or otherwise, that mainly concern those who are seeking to apply scientific methods of investigation to economic problems.'

II

THE EFFECTS OF POLLUTED WATERS ON FISH LIFE.

A PRELIMINARY REPORT BY PROFESSOR A. P. KNIGHT, QUEEN'S UNIVERSITY, KINGSTON, ONT.

Before entering upon my formal report, I wish to express to the Dominion Government, through Professor Prince, the Commissioner of Fisheries and Director of the Marine Biological Station, my warm appreciation of the foresight and spirit which prompted the establishment of a marine biological station in Canada. I have no doubt that every year will demonstrate the wisdom of founding such a station. The privilege accorded me at it, during the past two seasons, in the way of collecting and studying marine and fresh-water animals, has been a source of keen enjoyment. The following report is tendered in the hope that the facts submitted may help, in a humble way, to elucidate some of the problems which are presented to the Dominion Fisheries Department from time to time for solution.

It was Professor Prince's report for 1899 to the Honourable Sir Louis Davies which suggested the inquiry described in the following pages. Its prosecution at St. Andrews, last summer (1900), was greatly aided by the assistance and advice which I received from the Commissioner and I desire to make public acknowledgment of the same.

The pollutions with which I experimented were *(a)* sawdust, *(b)* waste water from a nail factory, *(c)* waste water from two pulp mills, and *(d)* waste water from gas works.

The general method of investigation consisted in adding varying percentages of the waste water to fresh water, or to salt water, according to the kind of fish experimented with, and then immersing the living fish in the mixture, and noting the effects upon them.

A 'control' experiment was usually carried on along with those on the waste water. This 'control' consisted in placing a normal vigorous animal in unpolluted water, so that observations on fish immersed in the polluted water could be compared with observations upon the animal in normal water.

PRELIMINARY EXPERIMENTS.

Some preliminary experiments were undertaken for the purpose of determining, first, the shape of the vessel in which the fish should be confined, and secondly, the volume of water which should be used in proportion to the weight of the fish. Information was needed as to whether the dishes used should be broad and shallow, or tall and narrow; also whether large quantities of water should be used in proportion to the bulk of the fish, or whether smaller quantities might suffice.

The following experiment repeated a number of times settled the first point. Two rock bass (*Ambloplites rupestris*, Rafinesque) of equal weight, were placed in separate vessels, each vessel containing 3½ litres of lake water. One vessel was an ordinary agateware baking pan, 13¼ inches long, 9¼ inches broad, and 1¾ inches deep. The other vessel

was a tall cylindrical museum jar (with an external diameter of 6 inches) the water in which stood 8¾ inches high. The experiment began at 10 a. m. At 5 p. m. the fish in the tall vessel was lying on its side in a dying condition. The next morning it was of course dead, while the one in the shallow pan was quite lively. The same results occurred whenever this experiment was repeated.

Such experiments evidently show that ventilation or aëration of water is as important in fish-respiration as ventilation of air is in mammalian respiration. They show that ventilation goes on naturally and readily in the shallow water of a broad flat vessel. In such a vessel, a large surface of water is exposed to the air. As the oxygen dissolved in the water gets used up by the fish, fresh oxygen is absorbed from the air, the absorption being promoted by the movements of the fish, which agitates the water and exposes a fresh surface to the air. On the other hand, the water in a tall narrow vessel has a comparatively small surface exposed to the air, and a fish, usually lying at the bottom, does not agitate the surface so as to promote aëration of the water. These experiments throw light on how trout can live in very tiny streams of water in dry weather, and they explain also how minnows can live all day long in a little water in the bottom of a fishing boat.

The second question, 'should large quantities of water, or comparatively small quantities of water be used in the experiments?' was not so easily answered. The quantity was, of course, found to vary with the extent to which the water was ventilated or aërated. If artificial ventilation were applied to the water, then a relatively small volume would do; if no artificial ventilation were applied, then, of course, a much larger quantity of water had to be used, and it had to be placed in a broad shallow dish.

In connection with this subject, a number of experiments were tried for the purpose of determining the length of time that unit weight of fish (1 gram) could live in unit volume (1 c.c.) of unaërated water. Fish were weighed and placed separately in closed vessels completely filled with a known volume of water, and the length of time they lived was carefully observed. The following was a typical experiment: Weight of fish, 76 grams; volume of water, 5,530 cubic centimetres; lived six hours. Therefore, 1 gram weight of fish lived in 1 c.c. of unaërated water for about five minutes.

Ten similar experiments on rock bass of different sizes gave seven minutes as the average time during which unit weight of fish could live in unit volume of unventilated water, the range being five minutes as the minimum and nine minutes as the maximum. The temperature of the tap water with which these experiments were conducted was 22° C. When the water was cooled down to 4° C., the fish lived for a shorter time. When the temperature was raised to 32° C., they lived for a shorter time also.

These figures for the duration of life in fish confined in a limited quantity of water are interesting when compared with those obtained by Paul Bert for mammals breathing a limited quantity of air. Five experiments by this observer gave eight minutes as the average length of time during which unit weight of mammal (1 gram) lived in unit volume (1 cubic centimetre) of confined or unventilated air.* Mammals, therefore, use about six times as much oxygen as fish do in the same length of time.

These experiments suggested the possibility of determining the smallest amount of water in which a fish of a given weight could live for many hours or even days, on the supposition that this minimum quantity could be kept perfectly ventilated. Of course a fish requires something more to maintain life than aërated water. Free movement is essential, not to speak of food; but apart from these and similar considerations it seemed worth while to conduct an experiment or two on the respiration of a fish in a minimum amount of water.

With this object in view, a perch (*Perca flavescens*, Mitchell) was placed in 600 cubic centimetres of water in a jar, and arranged so that a continuous stream of air was bubbled through it. There was just enough water to cover the fish. Its position in the bottle tended to throw the animal on one side, in which position it seemed to stiffen, for, at the end of 24 hours, it was removed from its prison with its body slightly curved to one side. In three or four hours it could swim slowly about the aquarium, but for

* Leçons sur la physiol. comp. de la respiration," Paris, 1870, page 510, quoted in Schäfer's Text-book of Physiology, vol. i, page 743.

days afterwards it had a kink in its tail. This experiment showed that unit mass of fish had lived in unit volume of aërated water for 130 minutes.

In another experiment of a similar kind a small rock bass lived for 74 hours in 700 c. c. of aërated water.

RATE OF RESPIRATION.

A few observations were made upon the rate of respiration in fish confined in an aquarium. Four rock bass breathed at the rate of 44, 48, 52, and 56 per minute in water at 22°C. Rate of respiration here means the rate at which the gill covers were raised and lowered. When the water was cooled down to 5°C. the rate in one of these animals fell to 16 per minute, and when warmed to 32°C, the rate increased to 112 per minute.

Warm water (32°C.) had another peculiar effect on rock bass. It caused the pigment cells of the skin to spr ad out and give a decidedly darker hue to the whole fish. This became particularly marked when the animal was returned to the aquarium where it could be compared with the other fish. I had often observed that sunlight and darkness produced a similar effect upon the chromatophores of fish embryos, but I had never observed this marked effect of warm water.

Muscular exertion also increased the rate of respiration.

EXPERIMENTS WITH SAWDUST.

About two miles up James' brook, from where it empties into Chamcook harbor, near St. Andrews, N.B., was the site chosen for this experiment. The water was clear and cool, and runs over a gravelly and stony bottom—a typical trout stream containing a fair number of *Salvelinus fontinalis*. Primitive forest or second growth elder, balsam, cedar and various kinds of hardwood covers the district through which the stream runs.

A box 3 feet long, 2 feet wide, and 14 inches deep, lined with zinc, was used as a tank in which to confine the sawdust and the living fish. The box was covered with mosquito netting and over this wire gauze. A pailful of old, that is water-soaked, sawdust and about a quart of fresh sawdust was placed in the tank. A trough 12 feet long conveyed water from a dam on the stream down to the tank. The tank itself was immersed in a small pool, the water in which came up the sides of the vessel to within three inches of the top. The temperature of the water in this pool was 17·3°C. in the sun, and 16·9°C. in the shade.

An hour's fishing in the brook furnished four speckled trout and a post-larval eel for the experiment. Two of the trout had been badly injured in the eye by the fish-hook. All five animals, along with a frog, were placed in the tank about 5.30 p.m. of July 6, and the water turned on. The flow was abundant and continuous, the descent from the dam being sufficient to stir up the saw-dust into a gruel-like mixture as thick as in any mill stream no matter how much sawdust may have been thrown into it. All the conditions were therefore, as much as possible like those prevailing in a sawdust polluted stream.

The tank was not visited until July 11, when all the animals were found active and apparently healthy. The frog was lying at the bottom as he could get no air at the top, on account of the cover. About half-a-pail more sawdust, some sand, and gravel were added, and the tank again closed.

On July 14 the tank was again visited. All four trout were alive, active and apparently well. The eel escaped as the cover was removed. The frog was dead. About a dozen earthworms were thrown into the tank, but the trout did not touch them so long as they were under observation. More sawdust was added and the tank closed.

On July 21, three-fourths of the water in the tank was emptied out, and the tank containing the four trout was brought to the laboratory, St. Andrews, a distance of about three miles in a wagon, and part of the journey over a very rough road. On examination the four trout were found to be very active, so active indeed, that they were only captured after emptying out nearly all the water.

This ended the experiment, and yielded the conclusion that if fish, so sensitive as the trout, could live in such a mixture for a whole fortnight, without apparent harm, in fact with recovery from severe injuries, then any fresh-water fish could live in a mill stream or river, no matter how badly polluted with sawdust.

Dr. Stafford conducted a post-mortem examination on one of these trout, and found only two very small pieces of sawdust on one of the gills. Neither piece seemed to have injured the gills. A few filaments were slightly damaged at the outer end of one gill-arch, but there was no evidence that this condition of the filaments was due to the action of the sawdust.

My own post-mortem examination of two other of the animals showed no trace of damage from sawdust.

While the experiment seems conclusive as regards the fact that sawdust does not directly injure adult fish, it by no means follows that streams polluted by sawdust are harmless to fish life. Water-soaked sawdust may and no doubt does cover long reaches of river beds. The breeding grounds of fish may thus be interfered with. Fish that habitually spawn on sandy and gravelly bottoms are not likely to take kindly to beds of sawdust. Moreover, the sawdust may interfere with the development of aquatic insects and thus reduce the food supply. So that, although sawdust itself may not be hurtful to adult fish life, indirectly it may interfere seriously with the laying of the eggs and the development of the young. Further investigation is necessary.

On the whole, my observations corroborate those of Dr. H. Rasch regarding sawdust pollution of rivers in Norway, and quoted in Professor Prince's report of last year.

EXPERIMENTS WITH WASTE WATER FROM PULP MILLS, CHATHAM, N.B.

In my experiments with waste water from pulp mills, five kinds of fish were used, viz., stickleback (*Gasterosteus aculeatus*), 'white perch' (*Roccus americanus*), brook trout (*Salvelinus fontinalis*), rock bass (*Ambloplites rupestris*), sun-fish (*Lepomis pallidus*), and sea 'chub' (*Fundulus heteroclitus*).

As is well known, sticklebacks frequent brackish water, or fresh water near the sea. They are very hardy, and can live in stagnant pools and ditches, where no fish life would ordinarily be expected.

A stickleback and a sea-chub were placed in equal parts of pulp waste water and pond water. In less than an hour both were dead. The vessels used had a capacity of 5 litres, and were immersed in a pond, so that the temperature of the water used in the experiment was the same as that of the pond from which the stickleback was taken.

In another experiment in which the waste water formed 25 per cent of the mixture, two sticklebacks placed in the vessel at 5.30 p.m. of July 14, were found dead the next morning at 10 a.m.

Reducing the amount of waste water to 10 per cent, it was found that two stickleback placed in such a mixture on July 16, lived until July 27, when both specimens were liberated.

Trout were found to be much more sensitive to this pollution. One placed in a 10 per cent mixture of pulp-waste water and spring water, lived from July 21 at 5 p.m., to July 22 at 3 p.m.

White perch from Bocabec lake (near St. Andrews) lived in lake water polluted with 10 per cent of pulp waste water for about thirty-six hours.

Rock bass and sun-fish lived about twenty-four hours in a similar mixture, while fresh water clams lived for two or three weeks in it without apparent inconvenience.

These experiments indicate that river or brook water when mixed with 10 per cent of waste water from pulp mills, is decidedly poisonous to fish life. If, therefore, a larger quantity of this waste is poured into a comparatively small stream, it must result in the destruction of fish; if, into a large river, then it is difficult to see how any great harm can be done. The specific gravity of this pollution, 1·00005 (water = 1) being so very slightly greater than that of river water, shows that the water from pulp mills would mingle readily with that of any fresh water stream into which it was discharged, and unless the pollution equalled or exceeded 10 per cent, no great harm could be done.

These observations corroborate in a general way those of Dr. Philip Cox on the smelt (*Osmerus mordax*) and quoted in Professor Prince's report of last year. Any discrepancies may be accounted for by the fact that the properties of waste water from pulp mills differ at different stages in the manufacturing process.

The chemical analysis of this waste water, made after my experiments were completed, and published in an appendix to this report, shows that the mill from which the pollution came was a sulphite one.

EXPERIMENTS WITH WASTE WATER FROM THE GAS WORKS, ST. JOHN, N.B.

This waste water is much more poisonous to fish life than the former, and kills much more quickly. The very suddenness with which fish succumb to its effects indicates that death results in some cases, from poisoning with the sulphuretted hydrogen which the water contains. Confirmation of this view is afforded by the fact that if a fish does not die in the polluted water during the first 24 hours, it will usually live on in the pollution for several days. Besides, when a fish succumbs quickly, say in 10 to 20 minutes, to the effects of this gas, it could usually be resuscitated by transferring it to pure water. Within 15 to 30 minutes after transference, the fish was as lively as ever, especially if the water were agitated so as to increase the amount of oxygen dissolved in it.

The following were typical experiments. A *Roccus americanus* was immersed in a 5 p. c. solution of gas water in lake water, and in 20 minutes the fish was dead. Immersed in a 2 p. c. solution, the same kind of fish survived about half an hour. In a $\frac{1}{2}$ p. c. solution the fish lived about half a day.

Sticklebacks endured this poison a much longer time. Of two sticklebacks, placed in solutions of $\frac{1}{2}$ p. c. strength, one lived a day and a half, the other lived ten days, and was then liberated. I had reasons for suspecting that the animal which died was not healthy when the experiment began, if so, its death was merely hastened by the pollution.

Trout are very sensitive to the effects of this poison. At 4.45 p.m., July 21, I placed a trout in $\frac{1}{2}$ p.c. gas-waste water. In 10 minutes the animal was lying on its side at the bottom of the vessel. As it was evidently moribund, it was removed to fresh water which was agitated by pouring water upon it from a height. In 10 minutes the animal had apparently recovered, and lay quietly and comfortably at the bottom of the vessel. In half-an-hour more, it was very active, and frightened if any one approached.

A tom cod (*Microgadus tomcod*) was placed in a $\frac{9}{10}$ p. c. solution of this waste in sea water. In a few minutes it was lying on its side and in 15 minutes it was on its back. When returned to sea water which I agitated vigorously, the animal soon revived.

Experiments with smelt (*Osmerus mordax*) gave exactly similar results in $\frac{1}{2}$ p.c. solutions of this waste in sea water.

Fresh water forms like the rock bass and sunfish, and salt water 'chub' (*Fundulus heteroclitus*) were much less affected. These forms were kept from two to three days in the pollution ($\frac{1}{2}$ p.c. strength), some dying within 24 hours and some surviving several days. The explanation would seem to be two-fold. In the first place these fish are constitutionally more resistant to pollutions of all kinds. In the second place the sulphuretted hydrogen in the mixture would largely diffuse into the air, and decompose in the water in an open vessel during the first 24 hours. If the animal, therefore, survived this period, it died later on through the poisonous effects of the other ingredients of the waste, such as the sulphates and chlorides.

The chemical analysis given in the appendix, and made after my experiments were concluded, shows that this waste water is 'much more diluted than those ordinarily met with.' In estimating, therefore, the poisonous effect of gas waste water, these points must be kept in mind: first, the extent to which it is diluted with lake or river water before leaving the works; secondly, its specific gravity, 1·00123 at 15° C. (water = 1); and thirdly, the volume of the river, stream or lake into which the waste is discharged.

EXPERIMENTS WITH WASTE WATER FROM NAIL WORKS, ST. JOHN, N.B.

This pollution was the most deadly one examined. In many experiments $\frac{1}{10}$ per cent was sufficient to kill in a few hours. The most marked peculiarity in all the experiments made with this waste was that in a few minutes after mixing it with either fresh or sea water, a reddish brown precipitate began to form, and continued forming for several hours. The suspicion that this precipitate was ferric hydroxide, was confirmed by subsequent chemical analysis.

Microscopic examination of the gill filaments of fish killed by this waste, showed that death was caused by this adhesive precipitate sticking to the filaments. With a coating of this rust-like substance covering the gills, it is difficult to see how oxygen could pass into the blood and carbon dioxide could pass out, especially as the irritant seemed to cause a mucous or slimy exudation to form on the mouth-parts and gills

Experiments began with solutions of 6 per cent, 2 per cent and $\frac{1}{2}$ per cent, all of which were found to cause death in from half an hour to an hour. Reduction to $\frac{1}{4}$ per cent resulted in the death of the hardy stickleback in about five hours. Specimens were able to survive for two or three days when the solution was reduced to $\frac{1}{7}$ per cent. In fact, when any of the hardier fish, like Fundulus, the stickleback, or the rock bass were able to survive the six or eight hours during which the ferric hydroxide was being precipitated, they usually lived on for several days or a week.

More delicate fish like smelt and trout, however, succumbed to weaker solutions ($\frac{1}{10}$ per cent) of the poison, in from ten minutes to half an hour. Repeated attempts to resuscitate these fish by artificial aëration in fresh water proved failures. In the case, therefore, of the more sensitive fish, death is apparently caused by the absorption of the free hydrochloric acid and ferrous chloride. That small quantities of the latter were absorbed was proved by treatment of the gill filaments with ferro-cyanide of potassium. This I did at the suggestion of Professor Macallum. This reagent stained the filaments a blue colour, and subsequent examination of sections of these under the microscope showed slight absorption of the iron compound along the surface cells.

Attention is specially directed to the high specific gravity of this pollution, 1·1150 (water = 1). The effect of this would be to cause the pollution to fall to the bottom of a stream into which it might be discharged. This would result in the death of fish that habitually live in deep water, especially if the flow was sluggish. On the other hand, the great density of the pollution would increase the rapidity of diffusion throughout the fresh water, in accordance with the laws of diffusion of liquids of different density, and this would be followed by the formation of the precipitate already referred to, and ultimately the water would tend to become harmless.

ACKNOWLEDGMENT *re* CHEMICAL ANALYSES.

Before concluding this report I desire to acknowledge my great indebtedness to Mr. Frank T. Shutt, M. A., chemist at the Experimental Farm, Ottawa, for the labour and pains he has spent in making the analysis of the waste water from the gas works and from the pulp mills.

Mr. J. C. Murray, B. A , School of Mining, Kingston, has placed me under similar obligations for his analysis of the nail waste.

All the analyses were made at the end of the season, and after my observations had been completed, but I hope to be able to utilize some of the results next season if I continue this investigation.

As regards sawdust, it seems clear that future observations should be made where large deposits of this pollution occur in river beds. An attempt should be made to ascertain *(a)* whether adult fish frequent such places; *(b)* whether the sawdust affects the laying and development of the eggs, and *(c)* whether it interferes with the food supply.

Ottawa city itself might be as good a place as could be found at which to prosecute some of these investigations.

APPENDICES.

APPENDICES TO DR. KNIGHT'S REPORT ON THE EFFECTS OF POLLUTED WATERS ON FISH LIFE.

App. No. 1.

Central Experimental Farm,
Ottawa, October 30, 1900.

Report on Waste Water from Gas Works: Specific Gravity, 1·00123 at 15° C.

As received, this water was turbid, of a decidedly dirty, yellowish brown tint, and smelled strongly of tar and sulphuretted hydrogen. It showed a decidedly alkaline reaction when tested with litmus. On standing for some time (from a week to ten days), the water deposited a certain amount of tarry material and lost all odour of sulphuretted hydrogen.

With suitable treatment 'gas liquor' can be made a profitable source of ammonium salts. Until recent years this by-product or rather waste product, in the manufacture of coal gas, has proved a positive nuisance, danger and expense, for it not only pollutes streams into which it may be run, but also chokes up by the tar it deposits, the pipes and channel ways that conduct it away, make their constant clearing a matter of necessity. Now, practically all the ammonia of commerce is manufactured from it, for, as already pointed out, it is highly charged with salts of ammonia, especially the sulphate. Aniline dyes are also prepared from the tar it contains.

The probabilities are that if this waste water had been examined shortly after collection and a distillation made in the presence of an alkali, figures would have been obtained showing a considerable amount of ammonia and ammonium salts. As the sample, however had been collected some weeks before reaching the laboratories, and consequently the greater part of the free ammonia had escaped, this determination was not made.

By the method of analysis usually undertaken with potable waters, the following data were obtained :—

	Parts per Million.
Free ammonia	677·5 + x
Albuminoid and combined ammonia	364·5 + x
Nitrogen obtained as in determination of nitrates	1,644·6 + x

It has been remarked that this waste water contained, when received, a considerable quantity of sulphuretted hydrogen. This was not separately determined, but all sulphur compounds, after the necessary treatment of the liquor, estimated as sulphuric acid :—

	Parts per Million.	Grains per Gallon.
Sulphuric acid (SO_3) representing all sulphur compounds	1,013·7	73·06

The total solids amounting to 1,457·5 p.p.m. or 102·0 grains per gallon. The loss on ignition of this solid matter (salts of ammonia, tarry substances, &c.) was 574·0 p.p.m. or 40·2 grains per gallon.

An examination of the solid content furnished the following data :—

	Parts per Million of Waste Water.
Chlorine	277·7
Lime	34·5
Magnesia	50·4
Iron and alumina	11·2

On comparing the present results with those recorded for waste waters from gas works, there does not seem to be any feature that calls for special attention, save that it is much more diluted than those ordinarily met with.

FRANK T. SHUTT,
Chemist, Experimental Farms.

App. No. 2.

CENTRAL EXPERIMENTAL FARM,
OTTAWA, October 30, 1900.

REPORT ON WASTE WATER FROM PULP MILL : SPECIFIC GRAVITY, 1·00005 AT 15°C.

This water is of a rich yellowish-brown colour, somewhat turbid and gave a distinctly acid reaction. It possessed a decided but peculiar sweetish smell, as if changes induced by fermentation were going on. As this sample had been collected some weeks before it reached the Farm Laboratories, it is quite possible that this odour would not be perceptible in the freshly obtained waste.

The total solid matter by estimation was proved to be 1792·5 parts per million (125·5 grains per gallon.) On ignition, these 'solids' first blacken and char and then give off copious fumes of an acrid, strongly disagreeable character. The residue, which is white, amounted to 300 parts per million (21 grains per gallon.) The volatile portion consists largely of organic matter, but there is also present a notable quantity of sulphuric acid. The former is, undoubtedly, material from the wood which has been rendered soluble by the treatment it undergoes in the preparation of the pulp.

Further analytical work furnished the following data :—

	Parts per Million.
Sulphuric acid (representing sulphur compounds)	341·94
Chlorine	1·84
Lime	4·03
Magnesia	51·87
Iron and Alumina	2·00

An effort was made to estimate ammonia and ammonium compounds but without avail, owing to interference by volatile compounds which distilled over during the process, and which completely masked the reading of the distillates with the Nessler reagent.

The only features calling for special comment are : (1) The strong acidity, due largely to the presence of free sulphuric acid, and (2) a considerable amount of soluble organic matter, which, in decomposition, might give rise to compounds of a more or less disagreeable and noxious character.

FRANK T. SHUTT,
Chemist, Experimental Farms.

App. No. 3.

SCHOOL OF MINING,
KINGSTON, ONT., November 13, 1900.

REPORT ON EXAMINATION OF NAIL WASTE.

Qualitation.—Iron, traces of silica and zinc and of organic matter. Hydrochloric acid.

Quantitation.—Specific gravity of liquid = 1·1150.

By titration with $KNMO_4$, the total iron present was determined to be 4·3260 grams per 100 cc., or 3·88 per cent by weight. Of this iron, 3·9900 grams occurred in the ferrous state (3·57 per cent), and 0·3360 grams occurred in the ferric state (0·3013 per cent).

The total acidity, combined and free hydrochloric acid, was determined to be 6·3875 grams per 100 cc , or 5·7286 per cent by weight. Of this, 5·8582 grams (5·25 per cent) occurred in combination with the iron, and 0·5293 grams (0·474 per cent) occurred as free acid. Of the combined acid, 5·2012 grams (4·66 per cent) was in combination with ferrous iron as $FrCl_2$, and 0·6570 grams (0·589 per cent) was in combination with ferric iron as $FrCl_3$.

When one-tenth of 1 per cent (0·1 per cent) of this liquid was poured into a vessel containing 2 litres of water (tap water), a turbidity occurred at once and an adhesive precipitate of ferric hydroxide continued forming for several hours.

After between six and eight hours the precipitation seemed complete. The vessel was allowed to stand undisturbed for two days ; the precipitate was then filtered off and washed

Nearly the total iron contents of the two cubic centimetres of the liquid was precipitated by dilution, in this instance, to 2 litres. Out of a posssible precipitation of 0·0836 grams iron, 0·0798 grams iron was actually precipitated as ferric hydroxide.

Summary.

Specific gravity	1·1150
Percentage ferrous chloride	8·24
" ferric "	0·873
" free HCl	0·474

J. C. MURRAY,
School of Mining, Kingston, Ont.

III

THE CLAM FISHERY OF PASSAMAQUODDY BAY.

REPORT BY J. STAFFORD, M.A., Ph. D., TORONTO, November, 1900.

(With 4 Plates).

CONTENTS.

INTRODUCTION.

The possibilities of our Canadian clam fishery, whether viewed as an industry offering employment to numbers of men, or viewed as a source of food supply to both maritime and inland people, have, undoubtedly, not yet been sufficiently appreciated. The importance of the clam for bait purposes in the catching of fish, has not in this country received the attention that has been given it or its relatives in some other countries. Its wide distribution, its abundance, and the readiness with which it may be procured on our coasts, as well as the high market value it commands in the New England States are considerations that are full of promise.

Numerous shell heaps on the coasts of New Brunswick, Nova Scotia and Prince Edward Island, sometimes more than two feet deep and occupying several acres of surface, are convincing proof that the food value of the clam was early understood by our Indians. Clams have long been handled as food and as bait in this country, in the United States and elsewhere; next to the oyster they are the most important shell-fish of the American continent; yet, until a few years ago, little of real value had been gathered respecting its habits, its mode of propagation, &c., and even at the present time there are numerous questions with regard to organization, function, food, time and

manner of spawning, development, change of form and of habits in the young, rate of growth, &c., &c., which demand time, patience, trained observation, and inventive experimentation to elucidate.

THE EXTERNAL FEATURES OF THE CLAM (*Mya arenaria.*) Plates I and II, Figs. 1, 2.

Size.—*Mya arenaria*, the common clam, is a mollusk about four inches in length, two and a half inches in depth, and one and a half inches in breadth. Specimens may be found side by side varying considerably from the dimensions here given They have been reported six to eight inches in length on the one hand, and of course they occur of all sizes down to the verge of invisibility on the other. What is generally regarded as a mark of the adult animal is its ability to deposit eggs or sperm, but the acquisition of this power does not mean the arrest of further growth.

Shell.—One of the first features to be observed in the clam is that the animal is supplied with a strong, hard shell into which the soft living parts may be withdrawn. The shell is composed of two valves which occupy the same position with reference to the inclosed animal as the cover of a book does to its printed pages. The valves are convex externally, concave internally, and are held together at one margin by a sort of hinge, while at the opposite margin they are capable of being brought together or separated at will. The hinge margin marks the dorsal surface or back of the animal, and the open margin is the ventral surface. It will be noticed that the two halves of the shell are not exactly alike in size, shape or markings, and that one valve doubles over the margin of the other at the hinge. This is the right valve, the other, or smaller one being the left. If a clam is placed before the observer with its hinge uppermost, the larger valve to the right, and the smaller to the left, it will then be in its natural position for locomotion in the direction in which he is looking. The end turned away from him is its anterior end, and that turned towards him is its posterior end. It is lengthened antero-posteriorly, compressed laterally, while dorso-ventrally it measures less than its length, but more than its breadth. It consequently possesses three axes of different lengths — a longitudinal, a vertical and a transverse. The greatest breadth is just below the hinge, towards the ends and below it gradually narrows. At the ends the two valves do not fit close against each other, but are left 'gaping'—hence the British name of 'Gaper,' or 'Sand Gaper.' Each valve, viewed from the side, is oblong or somewhat oval in outline, with a series of concentric markings parallel with the margin below but narrowing to smaller and smaller dimensions as they approach the hinge. The more or less angular prominences near the hinge, where the concentric lines are smallest, are called the umbones or beaks. The right umbo is the larger. Starting from one of the beaks, the concentric lines indicate the different sizes of the shell at different periods, and were caused by temporary suspensions in the desposition of shell matter, followed by renewed activity when the increased growth of the animal required an enlargement of the shell. They must not be considered annual rings of growth, since the greater number of them originate during the first year of the animal's life. The shell is an exoskeleton, secreted by, supporting, and giving protection to the underlying parts. The greater part of its material is calcium carbonate (limestone), which produces an effervescence, or an evolution of bubbles, when hydrochloric acid is dropped upon it. On its outside may be found a thin, brown, horny, epidermal layer (periostracum), more or less worn off except in the creases and at the margins where it may also be found to continue on to certain of the more exposed soft parts of the animal. Under this, or coming to the surface where the epidermis is absent, is the thick, prismatic, porcellaneous layer, composed of polygonal calcareous prisms deposited side by side at right angles to the surface. Underneath this and only to be seen from the inside by taking off one of the valves, is the third layer of the shell, the nacreous or pearly layer, composed of numerous superposed films of calcareous matter. When a clam is taken unawares and before it has time to contract, or when it is left quiet for some time in a large glass of fresh sea-water, there may be other parts exposed, such as the siphons, the mantle and the foot.

Siphons.—The siphons, or funnels, are two muscular tubes bound together as one long, thick, fleshy mass, projecting from the posterior end of the animal between the gaping valves. One tube is placed dorsal to the other so that their combined depth is greater than their breadth, while their length depends upon the size of the animal and its condition of extension or retraction. In a medium-sized clam the siphons may reach four to six inches in length. At the outer end each siphonal tube is supplied with a number of stout fimbriae, or feeling hairs, that, besides receiving sensations of disturbance that may cause the withdrawal of the siphons, may also close the openings and prevent large particles of solid matter from entering. If, while a clam is lying with its siphons out, particles of carmine are dropped into the water above, it can be determined that there is a current of water entering the lower, larger opening, but that the carmine is repelled from the upper opening. It is through the lower of these siphons that the animal receives its supply of sea water, that, besides serving the purposes of respiration, also conveys the food matters upon which it lives. It must be borne in mind, however, that the mouth is at the opposite end of the body from the siphons, which latter are often called the 'neck,' or the 'head,' by fishermen and others, who distinguish different species by such expressions as 'the little necked clam,' &c. And, indeed, the long, extended, siphonal mass, with its blackened, cuticularized outer end, may well give rise to such an impression. Tracing the lower wall of the siphons forward it is found to stretch like a curtain between the vertical edges of the valves. This is a portion of the mantle, and is continuous round the front end of the clam, where, however, there is a vertical slit through which may be protruded the slender, soft, fleshy foot. Both mantle and foot can be better described later.

INTERNAL ORGANIZATION. Plate III, Figs. 3, 4; Plate V, Fig. 5.

When a clam is disturbed it of course contracts, closing its shell and holding it closed with great muscular strength. In order to learn its internal structure it is necessary to remove one of the valves. Insert the blade of a knife at the posterior end and draw it forward close against the left valve. If the knife is carried round the anterior end both of the stout muscles that draw the valves together will be severed. The left valve may then be lifted up and broken loose at the hinge. There will now be exposed, on the one side, the inner nacreous surface of the shell already mentioned, with a number of lines and marks to be further noticed; and, on the other side, the fleshy mantle, with several organs either exposed or shining through. (Fig. 3.)

As the two halves of the shell were seen to differ somewhat on the outside, so there are also differences on the inside; of these the chief difference is the presence, in the middle of the hinge margin of the left valve, of a strong, broad, cardinal tooth, projecting perpendicularly inwards. Between its outer, upper surface and the overlapping portion of the umbo of the right valve is the hinge ligament, an elastic, horny substance which occasions the divergence of the valves when the muscles are relaxed. Near the anterior end of the valve is the mark of attachment of the severed anterior adductor muscle, and half way between the tooth and the posterior end is the posterior adductor muscle, while extending from one to the other ventralwards is the pallial line, indicating the seam along which the mantle was held by the pallial muscles against the shell. Below the posterior adductor muscle the pallial line has a broad, deep indentation with its concavity looking backwards. This marks the position of attachment of the retractor muscle of the siphons.

Turning to the soft parts exposed, we shall be able to recognize the large anterior and posterior adductor muscles of the foot, whose fibres run across from one shell to the other. Behind the ends of the anterior adductor are the much smaller anterior retractor muscles of the foot, whose fibres pass down the front end of the abdominal mass to be inserted into the base of the foot. Just in front of the posterior adductor are to be seen the posterior retractor muscles of the foot. They converge from opposite sides, running inwards, forwards and downwards, to unite and join the upper posterior part of the visceral mass, over the sides of which their fibres spread. Below the posterior adductor muscle are the paired retractor muscles of the siphons,

and running parallel with the lower margin of the mantle on each side is a band of pallial muscles. At the posterior end of the animal are the retracted siphons, which, on account of the condensation of their epidermal layer, now appear quite black. The rest of the surface consists of the thin mantle, which may however permit faint outlines of underlying organs to be seen.

Mantle.—The mantle or pallium is a broad, thin lamella, hanging down on each side of the animal between the body and the shell. It occupies the same position with reference to the body and the shell that the fly leaves of a book do to the printed pages and the backs In this species the lower margins of the two flaps of the mantle are grown together, so that it is more like one's vest buttoned up the front, while the valves of the shell may be compared with an unbuttoned coat. There is this difference, however, that the mantle and the shell are real parts of the animal, and are attached firmly to the body along the dorsal line.

The siphons are really outgrowths of the posterior margins of the mantle, that have become united, developed their muscles, and have been otherwise specialized to perform a definite function. There are species of clam that have no siphons and the two flaps of the mantle remain separate all the way around excepting along the dorsal line. Then again there are others in which the posterior margins of the mantle flaps lie together in such a way as to form two openings that act as short siphons. In some the siphons grow out and remain separate. In this species the margins of the two mantle flaps have grown together all the way round with the exception of three small areas—one the split at the anterior end through which can protrude the foot, the other two being the dorsal and ventral siphonal openings. The walls around these latter have become extended backwards but the part separating the two openings has remained single, forming the ventral boundary of the upper tube as well as the dorsal boundary of the lower. The united siphons, thus originated, have increased their length and strengthened their circular and longitudinal muscles. The pallial muscles of the region have become the retractor muscles of the siphons, keeping pace with the growth of the latter, while their point of attachment has moved forward, occasioning the indentation in the pallial line already mentioned.

Branchial Chamber.—Make a longitudinal incision along the median ventral line of the mantle, carrying it back as far as to the base of the ventral siphon and forward through the anterior adductor muscle. Raise the upper, left half of the mantle and there will now be exposed the large branchial chamber with its contents. Posteriorly it will be seen to open to the outside through the ventral siphon, which is also called the branchial siphon. The retractor muscles of the siphons show through the mantle walls. The borders of the mantle are thickened and contain the glands that secrete the shell substance, which is built by the deposition of new matter at the edge. These glands can only be found by examining thin sections with the microscope, but at each side of the foot slit, on the inside, there is a patch of mucin-glands that in colour and structure are well marked from the surrounding tissue. (Fig. 4.)

Abdomen.—Occupying the anterior half of the mantle cavity is the plump, soft, fleshy abdomen or visceral mass. It contains the stomach and greater part of the intestines, the liver and genital glands.

Foot.—Anteriorly and ventrally the walls of the abdomen become more muscular and give rise to the small, extensible foot. This may contract to a mere knob, or be extended to a tongue shaped or even long, thin, ribbon shaped process. The foot is the locomotory organ of the clam.

Gills.—Suspended from the dorsal wall of the branchial cavity are four long, flat, striated plates—two on the left and two on the right side of the abdomen and extending back to near the base of the siphons. These are the gills or branchiæ. Each is composed of two thin leaves or lamellæ grown together along lines running upwards and backwards in such a way as to make a large number of nearly vertical water tubes, that open above into another chamber shut off from the branchial cavity. The lamella forming either surface of a single gill is perforated by gill slits arranged in rows corresponding with the water tubes. The sides of the gill slits are clothed with fine hair-like processes called cilia, that keep up such a vibratory motion as to drive water, brought into the branchial cavity by the branchial siphon, through the gill slits and water tubes

into the cavity above. The outer lamella of each outer gill is united above with the mantle, the inner lamella of the outer gill and the outer lamella of the inner gill are continuous, the inner lamellæ of the inner gills unite for a distance posteriorly and then they diverge round the upper part of the visceral mass to which they become united except for a space above the centre of the abdomen where there is a branchial cleft.

Labial Palps.—Between the anterior ends of the gills and the anterior adductor muscle are, on each side, a couple of small flaps termed labial palpi, looking much like miniature gills. They constitute an anterior and a posterior pair, the right and left palp of each pair being grown together at their bases, across the front of the abdomen. It is between the transverse balconies thus formed that the mouth is situated.

Supra-branchial or Cloacal Chamber.—To inquire further into the inner organization of the clam it will be of advantage to remove entirely the left half of the mantle and of the siphons together with the two gills of the left side. This will expose, lying above the posterior part of the large branchial chamber, a much smaller supra-branchial or cloacal chamber, continued posteriorly into the dorsal or anal siphon. The transverse partition, separating the cavities of the siphons, extends forwards as the line of union of the gills on to the dorsal part of the abdominal mass. Looking down upon that part of it which forms the floor of the supra-branchial chamber, one can see the four longitudinal rows of openings of the water-tubes from the gills. Curving over the posterior adductor muscle will be found the rectum or terminal portion of the intestine, which discharges by means of its anal opening into the cloacal chamber. Farther forwards, on the dorsal walls of the abdominal mass, are the small openings of the excretory and reproductive organs. Thus the water which has passed through the gills, the undigested matters from the intestine, the fluid excreta from the renal organs, and the genital products, are all thrown into the cloacal chamber and are swept by an exhalent current through the dorsal siphon to the outside. (Fig. 5.)

Digestive System.—The terminal openings of the intestinal canal have been already noticed; between these two points it has the form of a much coiled tube most of which lies in the abdominal mass. By dissecting off the left wall of the abdomen and carefully picking away parts of its contents the course of the intestine may be followed. The mouth lies on the anterior end of the visceral mass, behind the anterior adductor muscle and some way above the base of the foot. It is guarded by two pairs of labial palps or oral lobes, which are of importance in directing the food matters brought into the branchial chamber towards the mouth. The bases of the upper ones unite above the mouth forming an upper lip, and the lower ones in a like manner form a lower lip. The short œsophagus expands into a somewhat capacious stomach, which in the dead clam is usually empty and its walls thrown into folds. Surrounding the stomach is a lobulated, greenish or brownish coloured digestive gland or liver, whose secretion is poured into the stomach to aid digestion. From the stomach food passes into the intestine, which in fresh specimens is usually distended and dark coloured from its contents. The intestine bends alternately forwards and backwards as well as from side to side, making some half dozen folds while it passes downwards in the abdomen, it then runs backwards to near the posterior limit of the abdomen, turns upwards and forwards, and leaves the abdominal mass in the middle of its dorsal surface. Here it bends backwards and enters the pericardium, the cavity of which it traverses in the median sagittal plane of the body. This dorsal, posterior portion of the intestinal tract, known as the rectum, then runs over the posterior adductor muscle and opens by the anus into the cloacal chamber. From the posterior end of the stomach springs a diverticulum which contains a peculiar gelatinous rod called the crystalline style; very large in this species, curving round near the posterior and ventral surfaces of the abdomen to end at the base of the foot.

Reproductive Organs.—Filling a great part of the abdomen, and especially between the folds of the intestine, is the pale, yellowish genital gland—ovary in the female, testis in the male. (Plate IV., Fig. 5, G.G.) It opens by a pore on each side of the roof of the abdominal mass into the cloacal chamber above.

Excretory System.—Situated under the pericardium and in front of the posterior adductor muscle is the renal organ, kidney or organ of Bojanus. It is composed of right and left nephridia, each of which is a tube folded once upon itself with both ends turned

forward. The lower limb or brown, broad, thick-walled glandular portion bends upwards at its anterior end opening into the pericardial cavity, while the lower limb or thin-walled, non-glandular part bends downwards at its anterior end crossing the other portion and opening into the cloacal chamber. Lying in the mantle and body walls, near the anterior end of the pericardium, is the pericardial gland, red-brown organ or organ of Keber. It is thought to be also excretory in function.

Circulatory System.—The heart is situated in the pericardial cavity. It is composed of a median, thick-walled ventricle, pierced by the rectum, and a thin-walled auricle on each side, opening into the ventricle. Anteriorly and posteriorly the ventricle gives origin to aortæ, which divide into smaller arteries, distributing the blood to the mantle and the body. The mantle acts as a respiratory organ upon the blood, which is collected and conducted through vessels directly to the auricles; but the blood that goes to the capillaries of the different organs of the body is collected into a large vein lying between the nephridia, from which it must first pass through a capillary net-work in the walls of the kidney and then through the capillaries of the gills before it is carried as arterial blood to the auricles, whence it passes with that from the mantle into the ventricle.

Nervous System.—Cerebral ganglia connected by a commissure, lie one on each side of the œsophagus. Each of these is united by connectives with the pedal ganglion situated in the base of the foot, and with the visceral ganglion situated in front of the posterior adductor muscle. Both pedal and visceral ganglia show indications of being double, like the cerebral ganglia. From each cerebral ganglion spring two nerves—a short one supplying the anterior muscles, and a long one running forwards and downwards to the border of the mantle, where it divides into inner and outer parallel nerves. These course round the mantle rim and unite before entering the visceral ganglion. The outer one gives off twigs behind to the siphons. From the visceral ganglion arise nerves to the posterior muscles and to the gills. (Plate IV., Figs. 5, 6.)

It will be observed that the clam is bilaterally symmetrical, in that a vertical cleavage, falling along the median longitudinal axis, would divide the animal into similar right and left halves. The shells, the mantle lobes, the gills, palps, auricles, nephridia, genital openings and cerebral ganglia are paired, right and left; while those organs which lie in the median plane of the body, such as the foot, intestine, ventricle, are unpaired or single. As in a great many other mollusks, however, the valves of the shell present more or less of an asymmetry in consequence of their bilaterality not being absolute.

NEAREST RELATIVES OF THE CLAM.

'Clams or clamps is a shellfish not much unlike a cockle; it lieth under the sand.' Wood, 1684.

The term 'clam' is applied to at least a dozen different species of American double-shelled animals. To distinguish these, qualifying expressions are frequently used. Most of the names of the species *Mya arenaria* (Linnaeus, 1758) here dealt with are the following:—

The clam.
The common clam.
The long clam.
The soft clam.
The soft-shelled clam.
The sand clam.
The squirt clam.
The maninose clam.
The nanninose.

In England it is called:—

Gaper clam.
Sand gaper.
Old maid, &c.

The names 'the clam' and 'the common clam' are also used for other species, where *Mya arenaria* is not the most abundant. South of New York the common species is *Venus mercenaria ;* north of Boston *Mya arenaria* is the commonest ; while between New York and Boston they are about equally abundant, and there the first is distinguished as the 'hard clam' or 'quahaug,' and the second is the 'long clam' or 'squirt clam.' Since the common names differ with the locality even along the same coast, it is not surprising that they differ still more in different foreign countries as France, Germany, &c., and it will be at once evident that if the one species can be known in all countries by the same name it will be an immense convenience. Hence it has long been customary for zoologists of all countries to use a double Latin name for each species. The generic name Mya has been derived from an old Greek word μῦς or μύα, the name of a species of mussel. By Pliny it was called *myax* (*-acis*). The specific name *arenaria* is a Latin word meaning 'living in sand.' Another but smaller species of mya (*M. truncata*) occurs on our coasts. Its shell has a blunt (truncated) posterior end, and it 'gapes' still more than our common species. A couple of smaller species belonging to a different genus (*Saxicava arctica* and *S. rugosa*) but to the same family (Myidæ) are also to be found here. This family, together with the Pholadidæ to which the ship worm belongs, the Solenidæ to which the razor-clam belongs, the Mactridæ containing the hard shell or hen clam, and the Veneridæ including the round clam or little-necked clam, all have a deep sinus in the pallial line as already described ; while a number of other families, like the Cyprinida containing the sea clam or Black Quahog, and the Cardiidæ with the cockle, have no mantle sinus : their siphons are short and not retractile. All those so far mentioned belong to the order Siphoniata, in contradistinction to which must be named the Asiphoniata, a large order comprising such important families as the Unionidæ (our fresh water clams), the Mytilidæ (the edible mussel and horse mussel), the Pectinidæ (scallops) and Ostreidæ (oysters), none of which have siphons, and their mantles are quite open below. Both orders belong to the class Lamellibranchiata (Bivalvia or Pelecypoda), which along with the classes Gasteropoda (slugs, snails) and Cephalopoda (squid, devil fish) are grouped under the great sub-kingdom of animals called the Mollusca.

OCCURRENCE.

'You shal scarce find any Baye, Shallow Shore or Cove of sand, wyere you may not take many Clampes.'—Captain John Smith, 1616.

Geologically, the clam *Mya arenaria* occurred as far back as in the Miocene period. Geographically, it has a wide distribution in the northern parts of both Pacific and Atlantic oceans. In the former it is to be found up the west coast of Alaska and down the eastern coast of Asia to China and Japan. In the Atlantic it extends from North Carolina to the Artic ocean. In Northern Europe it is most abundant in the North and Baltic seas and extends south to France. It is scarce south of Cape Hatteras but abundant from New Jersey northward. On our own coast it has been reported from the Bay of Fundy, Passamaquoddy Bay, Annapolis Basin, Halifax Harbour, Prince Edward Island, Shediac, Bay Chaleur. It undoubtedly occurs, in suitable places, round the entire coast of our eastern maritime provinces. Such places are the more sheltered parts of the coast, where waves cannot carry away their banks or heap sand above their burrows.

Passamaquoddy Bay, sheltered by the numerous islands that separate it from the Bay of Fundy, is a particularly suitable location. Here there is but a small part of the coast with precipitous banks, but a great part consists of gently slanting beaches where the tide recedes 200 to 400 yards or more. Such beaches are to be found on the coast of Charlotte County, New Brunswick, in proximity to St. Andrew's, St. Andrew's Harbour, Navy Island, Chamcook Harbour, &c., where the clam diggers mostly work. But clams occur all round the bay, on both the mainland and at many places on the islands. The littoral distribution of *Mya arenaria* varies with the conditions. In some places it is to be found near high water mark, while it is stated to occur at a depth of more than 100 fathoms. Speaking generally, on such beaches as I have mentioned, it is

chiefly sought for and is most abundantly gathered along a belt about 200 feet broad at half-tide level.

The most favourable soil appears to be that which forms what the people call mud-flats. This is composed of fine sand mixed frequently with a large proportion of black mud containing organic waste matters. Such soil has originated by the attrition and disintegration of rocks ; the transportation of dirt and vegetable substances from the adjoining land ; the decay of marine plant and animal bodies, sea weeds, shells, worms, fish, &c. The aggregation of such soil can of course take place only in sheltered places, where it would not be carried away by strong tide-currents, waves and storms. Hence the abundance of clams in estuaries, bays, coves, and such like situations. They do occur in many places in gravelly soil, even in stony and rocky places, but rarely in sufficient numbers to be of economic value, and besides they are mostly of small size. The habitat also effects a distinct difference upon the external appearance of the shell. Those from sandy ground have a white, chalky shell and a regular shape ; those from gravel are similar in colour but are liable to be smaller and more dinged ; but those taken from mud are bluer in colour, often with a brown marginal band containing an oxide of iron, and are of large size.

The natural position of the clam is with its anterior end sunk farthest in the soil and its siphons pointing upwards. It is usually buried to such a depth that the siphons can reach to the surface. Walking between tide marks over an area inhabited by clams, one observes numerous round holes in the ground from which come spurts of water occasioned by the violent closing of the clams when they feel the pressure communicated through the ground several feet in advance. Hence the name 'squirt clam.'

FOOD OF THE CLAM Plate IV., Fig. 9.

The structure of the clam precludes the possibility of its having rapacious habits. It is not provided with eyes wherewith to spy out its food, nor with limbs to give it speed in locomotion. Neither does it possess jaws, or teeth to bite and comminute large objects. It leads a sedentary, solitary life (which may account for the English name 'Old Maid'), buried in its cramped lodgings, and depending for sustenance upon the minute suspended particles that are carried to it by the sea water above. Unfavourable as this mode of procuring food may seen, yet it is the one made use of by vast numbers of animals, and the large size, plumpness and flavour of the flesh of the clam testify to its efficiency. To this end the clam is provided with such structural peculiarities in the formation and arrangement of its organs that it comes to be most admirably adapted to the conditions of its environment. The surfaces of its abdomen, gills and mantle are so well supplied with cilia, disposed in such a manner and vibrating in such a direction, that there can be a constant inflow of fresh sea water through the ventral branchial siphon, over the gills and to the mouth. It accordingly eats constantly, perhaps rather drinks constantly or at least often. One writer has suggested that the expression 'As happy as a clam' may have originated from the fact that 'it is never long between drinks.' Since its food is obtained in this non-selective, mechanical fashion, it is plain that particles are often carried into the mouth that are not proper food. One has to bear this in mind when investigating the contents of its stomach with a view to ascertaining what it feeds upon. Sand is found in considerable abundance in its digestive tract. Sometimes there are found particles which do not ordinarily belong to sea water. Examination of numerous specimens will decide what constitutes the staple food of this mollusk. In doing this it is best to use freshly obtained clams, otherwise much of the intestinal contents will be unrecognizably digested. In many the stomach may be found empty, but the intestine will be quite full and marked out in its course through the light coloured reproductive gland by its dark contents. If some of this is spread out on a slide and examined by the microscope it will be found to contain sand or mud with microscopically small organisms and débris of larger ones. Of plants there may be diatoms, desmids, filamentous algæ, spores of the higher algæ, fragments of vegetable matter, &c. Of animals there may be Rhizopods like Amœbæ and Foraminifera, Flagellata like Euglena and the Monads, infusoria like Paramœcia, bits of sponge with spicules,

minute worms like Planarians and Nematodes, the larvæ of larger worms, little Crustacea like Cyclops and Cypris with cast-off appendages of larger forms, insects like mites, ova and the larvæ of various salt-water animals. Diatoms, from their abundance and constancy of occurrence, may be considered the chief article of food. Experiments have been carried on with a view to discover whether clams exercise any selecting power over the food offered them. Finely divided flesh of fish or of shrimps was brought to the open siphons of living clams and let drop so as to be carried inward by the inhalent current with the result that the clams would close their siphons, or if at first accepting the food it would be instantly expelled; but when instead of fish or shrimps, diatoms were used the clams would continue to accept them.

REPRODUCTION—SPAWNING.

Until quite recently little attention has been directed towards the time and character of the spawning of the clam. It has been stated on the one hand that the clam spawns in September and October; on the other hand this was said to take place in June and July; only last year was published the statement that the clam spawns twice each season. Again, statements have been made in an authoritative style concerning the care of the brood, where it was clear that the author was judging by analogy with fresh water forms possessing considerable differences in structure, habits and environment, instead of describing from observation. During last summer I examined clams every week from the 20th June to the 25th September, and I never found any with ripe ova or sperm. I had concluded that their spawning time was early in the season, perhaps in May, which also seemed to be borne out by the presence of small clams that were to be procured in the sand at certain places at the very time when, according to one statement, the mature clams should have been spawning. Since the completion of my observations I have received a copy of a report by A. D. Mead, entitled, 'Observations on the Soft Shell Clam' (reprinted from the 13th Ann. Report of the Comm. Inl. Fisheries, Providence, R.I., Jan., 1900), in which from a study of clams in Narragansett Bay during the summer of 1899, the author was able to write: 'The exact limits of the egg-laying period of the clam have not been determined, but it probably extends through the months of May and June.' He examined clams on the 8th and 12th May, and found them full of sexual products that appeared to be nearly ripe. On the 22nd May he was able to fertilize eggs from a female by adding to the water in which they were kept some sperm taken from a male, and he followed the early stages of development.

As the author of the above report does not describe the sexual elements, and as I have not studied the ripe elements of the clam on account of not having been on the spot early enough in the season, I shall here insert some observations I made on the horse mussel (*Modiola modiolus*). This species, although more closely related to the edible mussel (*Mytilus edulis*) than to the clam, yet resembles the latter in its habit of burrowing its anterior end into the gravel, while the edible mussel fastens itself on the exposed surfaces of rocks. The horse mussel is less common in Passamaquoddy Bay than either the clam or the edible mussel, and finds fewer localities that offer it suitable accommodation. Generally, it may be expected near low water mark, in the bottoms of gravelly pools left by the receding tide, and in such positions near the outlet of these that, during the absence of the tidal water below there is a constant supply of salt water from the pool above. Such places are easily found on the 'Point' at St. Andrews, at the entrance to Katy's Cove nearby, on Pendleton's Island and elsewhere. This mollusk, belonging to the same family as the edible mussel, resembles it in the shape of the shell, the absence of siphons, the free borders of the mantle, and the possession of a byssus—a tangle of stout threads protruding from between the valves and fastening it solidly to rocks, stones or gravel. It is frequently larger than either the clam or the ordinary mussel, has a brown shell (whereas the other mussel has a dark blue shell), and is generally more or less bearded on the sides, and often partly overgrown by sea-weeds or other organisms. It was not until 1884 that the sexual characters and reproductive elements were studied, in the common British edible mussel by Professor McIntosh, of St. Andrew's, Scotland. He found that there were male

and female individuals, and that they attained to full reproductive maturity in April. For several months previously the reproductive organs had been gradually developing and ripening their elements, as also for some time afterwards there was a slow decline in the efficiency and size of these organs. While the time he mentions agrees tolerably closely with that of our common clam, it seems somewhat remarkable that the horse mussel should breed late in the season. During the month of September, the sexual characters of *Modiola modiolus* are very evident. Unlike *Mytilus* in which the development in size and colour is chiefly in the dorsal and lateral parts of the mantle, in this species the increase in size is almost entirely confined to the visceral mass. It does not appear possible to distinguish male and female individuals from the closed shell, but when the shell is gaping open one can distinguish them at a glance. The large distended abdomen of the female is a bright orange, while that of the male is yellow. The mantle in each is yellowish, but in the female its edges become more orange, while the gills of both remain brown. I have found no mention of sexual coloration in the clam, but clam diggers have informed me, upon being questioned with regard to this point, that at a certain time in the spring clams are not good to eat, and are greenish in colour. It will be interesting to discover if this statement has reference to the ripening of the reproductive elements, or if it has reference to another phenomenon that is occasionally produced when clams feed upon a particular species of diatom.

The sexual elements are ova and sperms (Plate IV., fig. 7). The ova originate in the ovary of the female, and sperms in the testis of the male. Both these organs are situated in the abdomen, round the coils of the intestine. Ripe ova, disconnected and free from pressure, are spherical, but when viewed in number, and more or less subject to pressure from their neighbours or from the cover glass in a microscopic preparation, they are more or less oblong or oval, and measure about $\frac{1}{10}$ mm. in diameter (the one in the drawing measured ·100 x ·120 mm.) The egg is surrounded by a membrane, under which is a pale layer ; then follows yellowish brown granular protoplasm, in which is situated a large pale nucleus containing a nucleolus. The sperm cells are pin-shaped with a large head, and a long filamentous tail. The head is ·005 mm. long, and is oval in form or top shaped. At the small end there is a smaller constricted part which tapers off to a point, corresponding to that upon which the top spins. In the middle of the larger end of the oval the tail is inserted. This statement is at variance with the observation of Dr. John Wilson in the 4th Annual Report of the Fishery Board for Scotland, 1885, where it is stated that the tail originates from the constricted part. Eggs and sperms are shed through special ducts into the sea-water. It is not likely that sperm cells make their way, against the outflow of water, through the exhalent dorsal siphon, or, with the inflow, by way of the ventral siphon, gill slits, &c., to meet the eggs before the latter are extruded.

May 30, 1901, at Canso, N.S., I found sexually mature mussels and clams. I give below a comparison of the measurements I took at the time with those of the horse-mussel given in the text.

Modiola..	egg	·100 × ·120 mm.
	sperm	·005 mm.
Mytilus...	egg	·082 × ·090 mm.
	sperm	·0063 × ·0027 mm.
Mya	egg	·058 × ·062 mm.
	sperm	·0045 × ·0022 mm.

The measurements of the eggs are those of the shortest and longest diameters, and the measurements of the sperm are those of the length and breadth of the head only.

In all three the tails of the sperm cells are attached to the centre of the big end of the head. In Mytilus the sperm head tapers off to a long sharp point, the outline of the sides being *concave* rather than straight or convex. In Mya the sperm head tapers to a shorter blunt point, the outline of the sides being distinctly *convex*. Neither of them possesses the little *beaded* constriction as shown in the sperm head of Modiola.

Considering the similarity in structure, habits, habitats, &c., there can be little doubt but that the above account, as far as it has been described, might, with tolerable correctness be written also of *Mya arenaria*. Fertilization, or union of sperm and egg, takes place outside of the animals, in the sea-water. For one egg there are thousands,

perhaps millions, of spermatozoa. Only one sperm-cell is necessary for the impregnation of an egg. Judging by comparison with well known cases we have a right to conclude that, considering the sexes to be equally abundant, the great surplus of sperm-cells for each egg indicates the chances that each egg runs of failing to become fertilized. If it takes a million spermatozoa to insure the fertilization of one egg, then the egg must be subject to very unfavourable conditions. Nature has met these adverse conditions by increasing the number of chances, so that, where currents of water or other causes interfere, yet a sufficient number of eggs become impregnated to keep up the average number of individuals from year to year by developing new broods to take the place of those removed by accident, natural death, &c. When a sperm-cell has found an egg-cell it forces its way, head foremost, by violently flapping its tail, through the outer membrane. Having once gained entrance, it soon ceases to exist as a distinct organism and becomes absorbed into the protoplasm of the egg, which, in consequence, now assumes renewed vigour. The egg-cell soon divides into two cells, these into four, and so on until a considerable number of cells is formed. During the process of cell multiplication and hand in hand with it, the cells arrange themselves in such order and become modified in such ways that, in a short time, a free-swimming embryo results. This is so small as to be scarcely visible to the unaided eye. It differs from the adult in a number of respects, but perhaps the most important of these is its ability to swim freely in the sea-water. This is accomplished by means of a peculiar organ called the velum, which can be protruded from between its already formed tiny shells.—Fig. 8. The velum is well supplied with large cilia, arranged in a wheel like manner. This stage in the development of the clam is of great importance, for it is due to it that the clams are capable of becoming scattered so that some of them may find fortunate places, as well as become distributed in entirely new regions although of course not at once over great distances. After a time the young clam becomes too heavy to swim, settles upon sea-weed, stones, sand, mud, &c., entirely looses its velum, but remains capable of actively creeping about by means of its foot. At this period it may be less than $\frac{1}{50}$ of an inch in length. Upon finding a satisfactory situation, it sooner or later buries itself in the sand or mud and begins life after the fashion of its adult parents. In the paper already mentioned Mead wrote: 'By the first week in July, 1899, a great many clams had already found their way into the sand. At this time they were so small that they escaped general notice, ranging from a size at which they were hardly visible to 9 mm. in length. He performed a number of experiments in planting small clams with a view to finding out their rate of growth. Those at extreme low tide grew the most, while the rate of growth fell off in proportion to the height above that level. Thus a specimen 15 mm. long on July 22 was planted at low water, and on September 18 it measured 48 mm. Another 13 mm. long grew in the same time to 28 mm. when planted below half-tide mark. Proper precautions were taken to guard against error and a large number of experiments employed, with the result that they grew in two months to twice, three times, and in some cases four times their original length.' Another way in which their rate of growth was measured was this: On July 6 and 9 a pint and a half of small clams were planted in a box of sand. On September 18 4½ quarts of clams were taken from half the box. This is an increase of six times their bulk in 10 weeks. The same observer found at the beginning of the breeding season a ripe male 30 mm. in length, and a ripe female 50 mm. in length. In his experiments he raised clams over 30 mm. in length that were undoubtedly of that year's growth. It seems likely then that clams may become mature and reproduce when one year old, although it has been generally thought that they require three years to grow to sexual maturity.

ENEMIES OF THE CLAM.

Clams, although ordinarily buried out of sight, and consequently escaping the open, direct struggle that their relatives the mussels are subject to, are nevertheless preyed upon by a considerable number of animals. They may be exposed through the washing away of sand by storms, when they may be cast up on shore, or left to die in the sun,

or be subject to the ravages of gulls, cormorants, crows &c. In places along the New England coast pigs systematically visit, root up, and eat the clams. In Greenland they are sought after by the walrus, arctic fox, and birds. One has but to examine the contents of the stomachs of fishes to find that many of these like the cod, also eat clams when they can get the chance. The siphons of Mya are often to be found in the stomachs of the flounder and the sculpin, and the first also eats young clams. Star fish, one of the greatest enemies of the mussel, also attack the clam, and the large, round whelk bores holes into the shells through which it eats the flesh. Crabs should also be mentioned among the enemies of the clam. I have already referred to the shell heaps thrown from the wigwams of Indians as an indication of the number consumed by them. In some places the heaps consist chiefly of clam shells. I shall give in another place some idea of the number of clams used by the white man, but I should mention here that his ravages depend not entirely upon the amount dug for his own use or for sale to others, but that he leaves exposed great numbers of rejected clams to die in the sun or to fall a prey to fishes, &c., with the returning tide.

METHODS OF PROCURING CLAMS.

Formerly the common method of procuring clams was by means of a spade, or better, a flat-tined fork. At some places along the United States coast they have been ploughed out and then picked up. At present the instrument largely used is the so-called 'clam hoe.' Plate IV., Fig. 10. This is shaped like a hoe but has four flat tines about 10 inches long with the two outer ones about seven inches apart. The handle is only about 15 inches in length and makes with the tines less than a right angle. The tines are pressed, by a wriggling motion, into the ground, then the handle is raised and pulled and the clams picked from the dirt and put into a clam basket, which, when full, is carried and emptied into a sack or barrel near by. Before the return of the tide these are collected and drawn away by a horse and wagon. If the clams are to be kept a day or two before being shipped, this can be conveniently done by leaving them, in sacks, where the tide covers them for a good part of the day.

CLAM FISHERMEN.

On the Canadian coast the clam diggers may be classified as :—

1. Local clam fishermen.
2. Nova Scotia bait fishermen.

The local clam fishermen supply the villages and residents along the coast, or now and again fill orders to hotels, &c., farther inland, and also dig and sell to the clam dealers who make regular shipments to shopkeepers in Boston. For Passamaquoddy Bay the industry is centred in St. Andrews. The number of men engaged varies from time to time, but perhaps averages about 25. These are often line-fishermen or their sons, but others often engage in this work through the short season when it pays them, and return to their ordinary occupation when the clam business ceases.

The Nova Scotia bait fishermen are those who come annually from coast towns in Nova Scotia to procure clams that are taken to be used as bait for cod on the banks of Newfoundland. This year the number of vessels to visit Passamaquoddy Bay was fourteen, and the number of men 131. A fuller statement will be given under the next heading.

USES OF THE CLAM.

1. Clams as Food.—Next to the Vertebrates, the most valuable subdivision of the animal kingdom is the Mollusca. Some of the uses to which they have been put are the following : Food, bait, fertilizers, ornaments, money, dyes, dishes, &c. Investigations into the prehistoric conditions of man show how long ago and how widely Mollusks

have been employed as food and as ornaments. On the coasts of Norway and Denmark there are banks of shells 1,000 feet long, 200 feet broad and 10 feet deep. These were for some time looked upon as natural deposits, but when they were found to contain remnants of stone fire-places, bones, rude implements, &c., it became evident that they were refuse heaps (kitchen middens) of the primitive fishermen-tribes of those districts. Similar shell-heaps occur along the coast of Canada and of the United States. A peculiarity in the use of shell-fish by the people of both continents is this, that whereas in Europe the mussels have been almost entirely used to the exclusion of the clams, on this continent even where both occur together and in equal abundance, clams are taken and the mussels left. If the latter are used at all it is chiefly as a fertilizer.

Of our food mollusks, the oyster is the most important. After this stands the clam, and then on a much lower level the scallop, quahog, periwinkle, razor-fish, mussel, whelk, &c. The clam is used to a much greater extent in the United States than in Canada, consequently a considerable proportion of those collected here for food purposes make their way to the former country. I subjoin here the summary of the clam fishery for *Mya arenaria* in the United States for the year 1880 :

	Bushels.	Value.
Maine	318,383	$ 90,056
New Hampshire	17,960	8,980
Massachusetts	158,626	76,195
Rhode Island	53,960	48,564
Connecticut	75,000	38,000
New York	340,775	255,581
New Jersey and Southward	100,000	45,000
Total	1,064,704	$562,376

In Prince Edward Island the clam is only used to a small extent. In Nova Scotia it is extensively used on the coast and there also exists some trade inland. In New Brunswick, likewise, there are considerable quantities used along the coast as well as small orders sent inland to hotels and shops. It is stated that in St. John there are 1,000 barrels a year sold. At present the best business is carried on at St. Andrews. It is of only two years' standing, and was occasioned by the formation of laws restricting the period for clam fishing in the United States Last year (1899) a New England clam fisherman came to St. Andrews and originated the business of supplying certain Boston fish stores with clams three times a week. He remained here from June 15 to September 15, i. e. during the closed season in his own state, after which time he returned to carry on the same trade during the remainder of the year. nearer his market. He dug clams himself and bought from the local clam diggers, to whom he paid $1.00 a barrel. The number of men supplying him was in the neighbourhood of 25. One man can easily dig a barrel at a single tide, and when the tides fall at favourable times in the day he can procure twice that quantity. The business however is not forced—a greater quantity of clams could be procured than the market demands. Last year the above mentioned clam dealer shipped to Boston 1,800 barrels in the three months he was here. Of the two full months, July and August, the greatest shipment was in August, the next in July, while of the two half months, June 15–30 and September 1–15, the greatest number was shipped in September. Beside this a local fish dealer shipped about 250 barrels.

During the present year (1900) the New England clammer shipped about 1,200 barrels, and a local shop keeper perhaps 100 barrels. The explanation of this falling off of the trade is that in the meantime, I am told, a business had sprung up at Yarmouth, Nova Scotia, whereby perhaps 200 barrels a week are sent to Boston. Most of those from St. Andrews are put up in ordinary barrels, on the tops of which are placed large lumps of ice kept in place by a canvas. The latter is readily fastened by first removing the upper hoop of the barrel and then replacing it over the canvas, the edges of which are clamped between the hoop and the barrel and then nailed. In this way the clams are kept cool and moist by the filteration of water from the melting ice above.

A local exporter however dispenses with the ice upon the principle that clams will soon die in fresh water, consequently, fresh water ice can not be good for them.

The price at which these can be sold varies somewhat according to the quality and size of the clams, the district from which obtained, the place where they are offered for sale, the weather, and a host of conditions. According to the New York *Fishing Gazette* for May 5, 1900, the price per barrel ranged from $3.50 to $6.00; per basket, $1.00 to $2.00; per 1,000, $5.00 to $6.00. Thirty years ago, according to Verrill, the prices in Connecticut stood at 95 cents, $1.25 and $2.00 per bushel, wholesale. These retailed in the market at 50 cents to 75 cents per peck, the smaller sized ones being cheapest. The Guilford clams were assorted and sold by the fishermen on the spot. The larger ones brought $3.00 per 100, and sold at New Haven at 60 cents per dozen. Smaller sizes brought 48 and 36 cents per dozen. During unusually low tides in winter a few extraordinarily large ones weighing 1 to 1½ pounds each, and measuring 6 to 8 inches in length, could be obtained. These sold for $1.25 a dozen.

On the Pacific Coast occur several large species of clam. One, *Glycimeris generosa*, Gould, called the Geoduck, ranging from Puget Sound to San Diego, California, frequently weighs from 5 to 7 pounds, and specimens have been reported weighing 16 pounds. These bury themselves 2½ to 3 feet deep, and to get one a man has to remove a barrel of mud. They are not very plentiful. One man states that at San Diego he did not find a dozen during several years, but that at Olympia three men could secure a dozen at one low tide. An ordinary specimen furnishes enough good, delicious flesh for four or five persons to eat at one meal. It is believed by those who have had an opportunity of studying them that they could be successfully transplanted to the Atlantic Coast.

Clams are eaten raw like oysters, or they are baked or steamed and served in the shell; or they may be taken from the shell, the more indigestible parts like the siphons being clipped off, and the rest fried with crumbled bread, seasoning, &c. They are used for soup, or from them is extracted a broth serving as a drink, or they may be pickled, salted, or made into chowders. At Oceanville and McKinley, in the State of Maine, were set in operation, in 1899, canning factories for clams. In October, at the latter place, 150 bushels a day were put up in chowder, or dry, or as broth, &c.

From Ganong's 'Economic Mollusca, of Acadia,' I quote the following paragraph: 'In the vicinity of St. Croix, "Clam Bakes," are an institution of venerable antiquity. The Indians probably had them, and congenial spirits from the border towns still delight to return at times to the ways of their clam loving predecessors. On some favoured spot on the shores of that splendid river they assemble by appointment, a great fire is built and by it many stones are heated and made very hot. The embers are then raked aside and upon the stones is placed a layer of wet sea weed, on which a layer of clams is laid. Then comes another layer of sea-weed and another of clams, and so on, the top of the whole being a cushion of sea-weed of extra thickness. Over the whole mass is perhaps a piece of canvas thrown, and in such an oven are the clams slowly steamed to the proper degree of deliciousness. A constant concomitant and the most pleasing feature of these banquets is the invariable good nature and good fellowship which prevails.'

There is sometimes developed in the gills and palps and occasionally in other parts, as the mantle and abdomen of clams and oysters, a bluish-green coloration. This has been very frequently looked upon as due to the deposition of a copper salt in the tissues so affected; some people have thought they could even recognize a coppery taste, and many believed the animals to be unfit or unsafe for food. This question has been studied by a number of biologists and chemists, and it appears that there is no well founded proof that the animals thus coloured are dangerous—that green oysters may be safely eaten is shown by the fact that they are often more highly valued in Paris and London because of their supposed better flavour. The presence of copper in the green parts of these mollusks was formerly denied, and it was found that the 'greening' was due to the absorption of a bluish-green colouring matter, allied to chlorophyll, from the protoplasm of certain Diatoms or Desmids. When ordinary uncoloured oysters are fed on *Navicula ostrearia* (var. *fusiformis*), they become greened, and on the contrary, when green oysters are isolated and fed on a different diet they lose their green coloration in a few days. At certain times and places this species of diatom may occur so abundantly

as to form almost the sole object of food of the oyster or clam. In other cases it is believed that the coloration is due to a green Desmid (*Peridinium*) upon which the oysters feed.

It has lately been shown by Herdman, Boyce and Kohn, of Liverpool, England, that oysters do possess small quantities of copper, iron, and sometimes manganese, in their tissues. There are several distinct kinds of greenness in oysters; in animals from certain places this is associated with a healthy condition, but those from other districts may be in an unhealthy state. Healthy French 'Huitres de Marennes' were found to contain more iron in other parts of the body than in the gills, the greenness of which could not be due to iron. Green Falmouth and other Cornish oysters were found to possess an abnormally large quantity of copper—as much as nine times the normal amount. Among certain American oysters selected green ones were shown to contain 3·75 times as much copper as the ordinary white ones, and the distribution of the excess of copper corresponded with that of the green colour. In such cases it is evident that the abnormal green coloration (green leucocytosis) is due to excess of copper. The excess is probably occasioned by a failure to remove the small quantity of copper which ordinarily passes through the system in the form of hæmocyanin of the blood. This is taken up by amœboid blood corpuscles (leucocytes) which, in the disturbed metabolic or diseased condition of the body, become aggregated in the blood capillaries of the gills, palps, and mantle, or massed in the heart.

In the mantle cavity of the clam occurs, in certain districts, a parasitic Nemertean (*Malacobdella obesa*). Although I have examined clams for portions of two years, and must have opened several hundred, I have never yet found a single individual in Passamaquoddy Bay that harboured this peculiar worm. It measures 30 or 40 mm. in length and 12 to 15 mm. in thickness, and could scarcely be overlooked even if one did not know about it; but I searched a good number of clams for the express purpose of obtaining this object, without success. The crystalline style, already referred to in describing the intestine, has been pointed out to me by clam dealers in the belief that it was a worm. In this connection I should perhaps mention the possibility of clams obtained from places near which sewers and offal of towns are emptied becoming a vehicle for the transference of bacteria to uninfected people. It has been shown that pure sea-water is detrimental to the growth of pathogenic bacteria, but that oysters inoculated with typhoid bacilli retained these for at least ten days, although they did not increase in the tissues of the oyster.

2. *Clams as Bait.*—For nearly four centuries important fisheries for cod, mackerel, halibut, &c., have existed on the 'Banks' of Newfoundland. Thither, especially New England and Acadian fishermen have been accustomed to resort to fill their vessels in the richest and most extensive cod-fishing district in the world. In the 17th, 18th and first half of the 19th centuries they fished with hand lines from the decks of vessels. About the middle of this century the practice of fishing with hand lines from dories was introduced. The vessels left home in April, May, and June and perhaps for a trip of 2½ to 4 months. In a vessel with a crew of 12 every one but the skipper and the cook was provided with a dory. Thus they could spread over a larger area, if any one found a good school of fish the others could flock towards him, and besides it was thought that the motion of the dory gave a quicker movement to the hook rendering it more attractive. It was believed that this method realized one-third more fish but of course there was the extra expense of the dories.

It was learned long ago that carnivorous fishes such as the cod were especially fond of mollusks. In the stomachs of Newfoundland cod are frequently to be found a shellfish closely allied to *Mya arenaria*. Our soft clam came into use at first for in-shore fishing of various kinds. As the fishing voyages lengthened clams were carried farther and farther to sea. They were used fresh, but later they were kept in wells in the vessels, or kept cool with ice. The vessels of Cape Cod, Gloucester and Maine, constituting the largest part of the fleet on the 'Banks' in the cod and mackerel fisheries, have no well, and are obliged to carry their bait shelled, salted, and packed in barrels.

The old style of mackerel fishing was to chop up clams and to sprinkle them overboard as 'toll-bait' to attract the mackerel to the serface. Now mackerel are caught in seines. Cod-fishing is conducted in two ways—by trawling or by hand-lining. In

the first clams are not used as bait but instead herring, mackerel, capelin, squid are employed. Clams are restricted to hand-line or dory fishing but they are not the only bait used in this fishery. Squid, capelin, birds (puffins, petrels), porpoise, &c., also have their place, but salted clams are the most satisfactory and are nearly always used except when fresh bait can be obtained. Several clams are used each time the hook is baited so that it is completely covered. While fresh bait will secure more fish, yet salt clams seem to be relished by cod and there is a great saving of time—the men are always supplied with bait and do not need to waste valuable fishing time to look for bait. Salt clams retain their flavour while fresh bait, that has been packed in ice, speedily deteriorates when exposed to the atmosphere in warm weather. In the hand line cod fishery on the 'Banks' about 100 vessels use salt clams (in 1886 the number was 97). Counting two barrels for each man this would make $100 \times 12 \times 2 = 2,400$ barrels. But as it requires 12 bushels of clams in the shell to make a barrel of salt bait, it thus takes 28,800 bushels of clams to supply annually salt bait for the New England vessels on the 'Banks' of Newfoundland. These have been largely obtained on the coast of Maine but every town on the New England coast, where clams could be obtained, became a station for bait supplies. Salt bait is of two kinds—'Full salting' is when one bushel salt is put to a barrel of clams, 'slack salting' or 'corning' is using ½ peck to 2 pecks salt for each barrel.

As early as 1763 there were regulations in Massachusetts regarding the number of clams that could be dug for each man for bait. In Maine they were first dug for bait about 1850.

Since the decline of the Labrador cod-fishing Nova Scotia has employed many vessels in the dory hand-line cod-fishery on the 'Banks.' In 1886, 5,137 barrels of clam-bait, valued at $28,230, were shipped from Maine to be used by provincials, and in 1887 4,430 barrels, valued at $24,440. In 1885, Nova Scotia supplied for bait 1,136 barrels, valued at $5,680, but the number has decreased since then, perhaps on account of the increase in the use of squid. Clams are also used by the fishermen of Gaspé and Quebec.

For the last twelve or fifteen years certain Nova Scotia fishermen have regularly visited Passamaquoddy Bay for the purpose of collecting clams to be used as bait in the Newfoundland cod-fisheries. Each sailing vessel was managed by a crew of about ten men, who brought all their requirements—food, clothing, clam-hoes, &c.—lived in their vessels, and at each ebb-tide went ashore in small boats to dig their clams. At the approach of flood-tide they would retire to their vessels, shell and salt down their clams, get their meals and take their rest. The usual time for this work is in the autumn or in the spring—during October-November, or April-May. They came usually from Shelburne, occasionally one vessel from Liverpool, Yarmouth, Annapolis or Halifax; and they returned to Lockport, seldom one to Yarmouth, LaHave or Shelburne. The first year for which I have obtained figures is 1889-1890. Only a single vessel was thus employed, the *Glide*, of Yarmouth, a vessel of 16 tons and with a crew of 8 men. It returned to Yarmouth, carrying 67 barrels of shelled clams. In 1894-1895 three vessels were employed, one of which made two trips—once in November and again in April. In all they carried away 299 barrels of clams.

In 1898-1899 14 vessels came with 120 men, and took away 1,532 barrels. During last season, 1899-1900, 14 vessels with 131 men carried off 1,765 barrels of salted clams. Neglecting the intermediate years but selecting the first, second and fourth of the periods mentioned, we will see a very substantial increase of the business for each five years of its existence. The following is taken from the records of the Customs officer at St. Andrews, who very kindly allowed me access to the papers concerned :

YEAR 1899--1900.

Leaving Date.			Schooner.	Tonnage	Of	Men.	To	Barrels.	Value.
1899.	Oct.	18	Trilby........	34	Shelburne ..	17	Lockeport	161	$805
	Nov.	2	Icelda........	19	" ..	7	"	110	550
	"	2	Kate...........	14	" ..	5	"	80	400
	"	3	Fleetwing	15	" ..	6	"	76	380
	"	3	....	40	" ..	10	"	175	875
	"	4	Charlie Richardson	26	" ..	11	"	175	875
	"	11	John Franklin....	18	" ..	5	"	100	500
1900.	April	20	Charlie Richardson	26	" ..	11	Yarmouth	126	750
	"	20	M. Owen..........	72	" .	15	Le Have.......	150	900
	"	28	Cilish	39	" ..	11	Lockeport ..	150	750
	May	1	Katie.............	14	Liverpool. ..	5	" ...	80	440
	"	3	Altona...........	28	Shelburne ..	11	" ...	160	800
	"	8	Trilby..........	31	" ..	11	" ...	127	750
	June	15	Mary Kate........	13	Halifax.....	6	Shelburne	95	475

It takes five barrels of fresh clams (in the shell) to make one barrel of salted, shelled clams, so that last year the Nova Scotia fishermen took 5,825 barrels of fresh clams—five times as many as are shipped to Boston for food. Many people in St. Andrews object that the Nova Scotians come and take nearly $6,000 worth, and without leaving a dollar in the town. Accordingly, last year, it was arranged to make it unpleasant for them, and an attempt was made to drive them away. But instead of going away as was desired, or of anchoring in the harbour or close by as formerly, they went to Chamcook Harbour, and the northern part of the bay round Bocabec, Digdequash, &c., where large quantities of shells mark their camping grounds. Judging from the large numbers of clams taken I should think that these fishermen do not so much require them for their own use as for selling to and supplying others who go to the fishing waters of Newfoundland. This supposition appears to be strengthened also by the fact that some of the vessels come twice a year—in the autumn and again in the spring.

REGULATIONS, TRANSPLANTING, ETC.

In Canada there are no regulations restricting the clam fisheries. The territory is free to everybody to dig where he likes, and when and how it pleases him, whether he is resident at the place or comes from other parts of Canada or the United States. The large number of clams yearly taken from the vicinity of St. Andrews is a good indication of the value that might accrue from a judicial working of our natural clam beds, and from encouraging and facilitating their growth, multiplication and distribution. There is, perhaps, no ground for fear of the clam ever becoming extinct on our shores. The fisherman has no use for undersized clams, and could not find them all anyway, so that there will always be enough of these left to grow up and continue to perpetuate the species. On the other hand the removal of so many of the largest clams from a small district each year cannot but have some effect in diminishing the amount of spawn deposited for replenishing the depleted mud flats. Besides there is the effect of interference with their natural beds. Of those clams rejected by the fishermen many large ones are broken and left to die and putrefy, while thousands that are too small for market are disturbed, injured or left exposed to the sun, or in such conditions that they are incapable of readily becoming buried again. The adult clam does not easily move to a fresh place when left exposed on the surface, neither can it quickly make a new burrow. Recognizing the small size of its foot in proportion to the whole size of the animal when compared with one of our fresh-water forms, I performed some simple experiments to discover if *Mya arenaria* could bury itself again after being once disturbed. A little way above low water mark I made several stone pens by placing good sized stones together in a circle, sufficiently close together to prevent egress of the clams or ingress of whelks, as well as to protect against tide currents.

From these pens I cleaned out the clams, whelks, smaller stones, &c., levelled down the dirt, and pressed it somewhat solid. Upon the surface I then placed a known number of good healthy clams taken from the same district, and kept watch every tide or two as to what progress they made in re-burying themselves in the ground. Some proceeded to burrow while others appeared satisfied to remain on the surface several days. In a few days most of them had made some headway but either from disinclination or inability their progress was very slow, requiring about two weeks to become covered or nearly so. I concluded that if they were left on the surface of hard clay or gravelly soil at some distance above low water mark they would be almost sure to die from exposure to the sun, not to speak of their risk of being captured by some enemy. The surface of ground that has been dug over for clams always shows numerous bleached shells many of which must have originated in the way described. The statement sometimes made by clam fishers, that the ground dug over one year is just as well supplied with clams the following year, can hardly be credited, if we consider a district from which they have been systematically extracted. In most places with which I am acquainted this is not done. The clammers dig here and there, wherever they can do the best, leaving intermediate patches undisturbed, which may be the ones searched next season. Some people seem to think that digging and loosening of the soil proves beneficial to the clams. This is generally a mistake. However valuable such procedure may be in the cultivation of potatoes it is a positive danger to clams. The loosened soil is in many places swept away by the tide, leaving a hard bed and loose stones. In very quiet, retired places where the bottom is mud such disturbance has less serious effects. Although the larval clam is free-swimming and the young clam is able to creep about with considerable speed and to burrow rapidly, when once it has found a spot to its liking and has become buried in the soil it ceases for ever to rove about. By the time it has grown to maturity its body is too unwieldy to admit of anything like satisfactory locomotion by means of its small foot. Its natural condition then is to live a sedentary life, protected within a more or less deep burrow, and any interference with this habit is a disadvantage against which it has to contend. The ability of the young clam to accommodate itself in mud, sand, gravel, clay, even rocky places, in protected coves, or in exposed banks, is an indication of the success with which it might be transplanted, even at long distances from its original home. As a proof of this we might mention the introduction of *Mya arenaria* into San Francisco Bay. Upon the completion of the transcontinental railroad, about 1869-70, some oyster dealers in San Francisco began to import small oysters by the car-load from the Atlantic and to plant them in San Francisco Bay, where in a year or two they grew to good marketable size. It was with these importations that the young of *Mya arenaria* were accidently introduced to the Pacific. It was first observed in San Francisco Bay in 1874 by Dr. Hemphill. He gave some rather small specimens to Dr. Newcomb for examination, who regarded them as a new species and named them *Mya hemphillii*. That it is a late introduction into those parts is also proved by the fact that mounds and shell-heaps on the shores of that bay fail to reveal any trace of the shells of *Mya*, although those of *Tapes*, *Macoma*, *Mytilus*, *Cardium*, &c., occur. These native clams are now almost superseded in abundance and good quality by *Mya arenaria*.

REFERENCE TO THE UNITED STATES AND GREAT BRITAIN.

The clam fisheries of the United States have been referred to in the foregoing pages. It will, perhaps, not be out of place here to say a few words about their equivalent in Great Britain. There the mussel (*Mytilus edulis*) is employed for the same purposes for which we on this continent use the clam. It is impossible to get a correct estimate of the amount used, since the figures given in the reports generally include the mussel among 'other shell fish.' On the coasts of Yorkshire and Durham they are employed as bait by a few hundred fishermen, but through decline of the mussel beds these men are sometimes forced to seek supplies from the continent, although formerly they were able to send mussels in quantities to the local markets and

to Scotland. Not to mention the demands throughout the provinces of England, there are, it is stated, more than 3,000 tons per annum consumed in London alone. In 1891 on the mussel beds of the Tees, eight boats were employed, where half a dozen years previously there were as many as fifty. This decline was due chiefly to the deepening operations of steam dredges. One man, using a rake from his boat, can procure in a day of eight or nine hours one bag of two bushels, which when sold for food brings four shillings. In favourable weather and a fortunate locality, a man can do much better than this, but the daily average is about seven shillings. Formerly twenty bags a day could be obtained by one man, and two men have been known to procure and send away fifty tons in a week. In 1887 there were ninety-one tons sent by train from Stockton, and 169 tons from Middleborough. This district also gives employment to fifty or sixty persons engaged in gathering cockles (*Cardium edule*). The mussel beds of the Esk employ 100 to 150 men, and those of the Humber about twelve men.

The mussel fisheries of Scotland are of much greater magnitude. It is estimated there are upwards of 20,000 tons used per annum. There are 50,000 fishermen, some using mussels as bait the year round, while all do for some part of the year. The bait is obtained especially from Greenock, Port Glasgow, Firth of Tay, and Firth of Forth. From native waters there were in 1892 some 247,411 cwt. taken, having a value of £14,534. In 1893, the quantity taken in the Clyde alone was 96,000 cwt.—two-fifths of all taken in Scotland. Bait is also obtained from Holland, Boston, Ireland, the Thames and elsewhere. According to a report in 1894, there were 14,500 cwt. shell-fish imported into Scottish ports, having a value of £4,000. These were chiefly mussels from Holland, and were worth 5s. 6d. per cwt.

In Scotland, as elsewhere, the broad stretch of mussel beds appeared to the early fishermen to offer inexhaustible supplies. But constant, unregulated, wasteful fishing brought about a state of decadence with consequent increase in price. The amount of change may be illustrated by the following statement of Mr. Johnston of Montrose: 'It is a fact that the Ferryden fishermen were offered the sands of Dun (north side of the river Southesk) at the beginning of the century at £5 per annum, and two dozen haddocks per week and one cod fish; but bait was so cheap at that time that the fishermen did not think it worth their while to accept the offer. These sands are now let to our firm for £500 a year.'

To the Scottish fisherman the mussel is the most important of all bait. The scallop, ink-fish, lugworm, herring, whelk, cockle, limpet, are other common baits. The number of hooks to a line varies from 500 to 1,200, according to the district. On an average two mussels are used to bait each hook, and to set all the lines at once it would require some 100,000,000 mussels. Jurisdiction is over waters for a distance of three miles (cannon shot) from the land, including bays, creeks, &c., not more than ten miles across the mouth. Beyond this belt the sea is the common fishing ground of all nations. Since general use of mussel beds tends to their ruination, it has become the practice of the Crown to grant privileges to individuals upon conditions which are likely to preserve the scalps and protect public interests. Persons trespassing are counted guilty of an attempt at theft and may be fined or imprisoned, but the rights of navigation in public estuaries are superior to those of fishing, provided the methods are not injurious to shell-fish. Depositing ballast or rubbish, placing of harmful apparatus, or otherwise disturbing the beds are, except under conditions, prohibited. The public can, however, fish for haddock, &c., over private mussel scalps in certain specified ways. Fishery orders may be obtained from the Fishery Board in Scotland, or from the Board of Trade in England for the purpose of cultivating shell-fish beds.

LITERATURE.

Linnæus—Systema Naturæ, XII. Ed., 1767.

Cuvier—The Animal Kingdom, London, 1834.

Deshayes—Traité élémentaire de Conchyliologie, 3 vol., Paris, 1839-1857.

Brown—Illustrations of the Recent Conchology of Great Britain and Ireland, &c., by Captain Thomas Brown, Mem. Manchester Nat. His. Soc. and Curator of its Museum, &c.

Johnston—An introduction to Conchology, London, 1850.

Keber—Beiträge zur Anat. & Physiol. der Weichthiere, Königsberg, 1851.

Leuckart—Zoologische Untersuchungen, Heft 3. Giessen, 1854.

Adams—The Genera of Recent Mollusca, 3 vol., London, 1858.

Brown—Die Klassen und Ordnungen des Thierreiches. 1862-1866, (New Edit. now appearing).

Jefferies—British Conchology, 5 vol., London, 1862-1869.

Gould and Binney—Report on the Invertebrata of Massachusetts, Boston, 1870.

Verrill—Report Invert. Anim. Vinyard Sound, Unit. Stat. Fish. Commiss. 1871-2.

Woodward—A Manual of the Mollusca, London, 2nd Ed., 1871, 3rd 1873, 4th 1880.

Von Jehring—Vergleich. Anat. des Nerven. und Phylogenie der Mollusken, Leipzig, 1877.

Sars—Mollusca Regionis Arcticæ Norvegiæ, Christiania, 1878.

Tryon—Structural and Systematic Conchology, Philadelphia, 1882-4.

Lankester—Mollusca, in Encyc. Brit. 1883.

Leunis and Ludwig—Synopsis der Thierkunde, 3 Aufl., 1886.

Fischer—Manuel de Conchyliologie, Paris, 1887.

Pelseneer—Introd. à l'étude des Mollusques, Bruxelles, 1894.

Tryon and Pilsbry—Manual of Conchology, Philadelphia (in course of publication).

Jour. Acad. Nat. Science, Philad., vol. II., 1822, p. 313.

Knight—Descrip. Catal. Fishes Nova Scotia, Halifax, 1866 (pp. 43-54, Edible Mollusca).

Proc. Calif. Acad. Science, Nov. 1874, Mya hemphillii).

U. S. Fish Com. 1873-4 and 1874-5, pp. 313-316 (De Broca, on the Soft Clam).

Proc. and Trans. Nova Scotia Inst. Nat Science, vol. IV., pt. III., 1877, pp. 321-330 (Jones, on Mollusca of Nova Scotia).

Verkrüzen—Zur Fauna von Neu Schotland und Newfounland. Jahr. der Deutschen Malak. Gesell. vol. V., 1878, pp. 208-230.

Hyatt—The Oyster, Clam, and other Common Mollusks, Boston, 1880.

1881. Bulletin U. S. Fish. Com. vol. I., p. 200-201, (Hemphill, on the Habits, &c., of the Goeduck).
Com. Fish. Maryland, Append. A., p. 83-91 (Ryder on develop. of clam).
American Naturalist, May p. 362-6 (Stearns).

1882. Bull. U. S. F. C., vol. II., p. 20-21.

1883. Bull. U. S. F. C., vol. III., p. 353-362 (Stearns, on the Edible Clams of the Pacific).
U. S. F. C., Com. Rep., p. lxxxviii.

1884. Bull. U. S., F. C. IV., p. 219-220.
U. S. F. C., Com. Rep. p. lxiv.

1885. U. S. F. C., vol. V., p. 174-176 (Ryder, on Rate of Growth, &c.)
p. 181-185, (Ryder, on Green Coloration).
p. 356-357, (Stearns, Clams of Pacific).
p. 426 (Intrd. into Delaware Bay).

1887. Fish. Indus. U. S., U. S. C. F. & F. Sec. V., vol. I., (Goode & Collins, on Bank Hand-line Cod Fishery).
Sec V., vol. II., p. 123-133 (Bank Hand-line Cod Fishery).
Sec. V., vol. II., p. 581-594 (Ingersoll, on the Clam Fisheries).
Bull. U. S. F. C., vol. VII., p. 447-464 and p. 425-428.
Bull. Nat. His. Soc., N. Bruns., No. VI., p. 17-61, (Ganong. Marine Mollusca.)

1888. 7th Annual Report Fishery Board, Scotland, (clam beds, &c.)
Challenger Report, part 74.

1889. Ganong—Economic Mollusca of Acadia, Bull. Nat. His. Soc., N.B., No. VIII.

1890. Smithonian Institution, Washington.—A Prelim. Catal. of the Shell-bearing Mollusks and Brachiop. By W. H. Dall.

1890. Bull. U.S. Fish Commis., pp. 389–436.—A Contrib. to our Knowl. of the Morph. of Lamellibr. Mollusks. By J. L. Kellogg, Ph. D.

1891. Jenaiscne Zeitschrift für Naturwissenschaften 25 Bd.—Thiele, Die Stammeswerwandschaft der Mollusken.

1892. Jena Zeit. Bd. 27—Rawitz, Der Mantelrand der Acephalen.

1893. U. S. F. C. F. & F., Com. Rep. (Lotsy. Food of the oyster, clam, &c.)

1894. U. S. F. C, Com. Rep., p. 619, 693 (Literature).

1898. 12th Ann. Rep. Com. Inl. Fish., Providence.
Bull. 51 R. I. Coll. Agric. & Mechan. Arts.

1900. 13th Ann. Rep. Com. Inl. Fish., Providence, Jan., 1900.
Observations on the Soft Shell Clam. By A. D. Mead, of Brown University.
The Fishing Gazette, New York, May 3, '94; May 9, '96; May 16, '96; June 6, '96; Oct. 14, '99; May 5, 1900.
Forest and Stream, &c., New York, Feb. 17, 1900.

1880. Report Com. Fish., Maryland, p. 1-81 (Brooks Develop. Amer. Oyster).

1885. Annals & Mag. Nat. His., (Feb., '85).
(Prof. McIntosh, Reprod. Mytilus edulis).
Bull. U. S. F. C., p. 161 (Verrill, How long will Oysters live out of water?)

1886. 4th Ann. Rep. Fish. Bd. Scot., 1885., p. xxiii., lvi., 218-222 (Wilson, Life History of the Mussel.)

1887. 5th Ann. Rep. Fish. Bd. Scot., 1886, p. 246-256 (Wilson, Devel. Mussel.)

1888. Ann. Mag. Nat. His. (Dec), Prof. McIntosh on the Development of Mussels.
7th Ann. Rep. Fish. Bd., Scot., p. 327-341 (Fullerton on Mussel Fishing at Montrose).
8th Ann. Rep. Fish. Bd., Scot., p. 293.
9th Ann. Rep. Fish. Bd., Scot., p. 184, 212.

1891. Mussels and Mussel Culture. By Wm. King, Budle Bay, England.
Report on the Mussel and Cockle Beds in the Estuaries of the Tees, the Esk and the Humber. By Prof. McIntosh.

1893. Report for 1892 on the Lancashire Sea Fisheries Laboratory at University College, Liverpool. By Prof. W. A. Herdman.

1895. Special Reports (II. Peculiarities in the Breeding of Oysters). By Prof. E. E. Prince, Ottawa, Canada.
13th Annual Rep. Fish. Bd., Scot. (Fullerton on Hist. Mussel Culture at Montrose).
Mussel Culture and Bait Supply. By W. T. Calderwood, London, 1895.

1898. Proc. U. S. National Mus., XX. Revision of the Deep-water Mollusks. By A. E. Verrill and K. J. Bush.

1899. Report for '98 on the Lancashire Sea Fish, Lab. at Univ. Coll., Liverpool, p. 62-67; Oysters and Disease, by Prof. Herdman, p. 67-79; Iron and Copper in Oysters, by Kohn.

DESCRIPTION OF PLATES I., II., III., IV.

PLATE I.

FIG. 1. *Mya arenaria*, natural size, from left side. The clam is represented in its usual position buried in sand, siphons stretching to top of burrow.

PLATE II.

FIG. 2. Ditto from left ventral surface, to show foot, mantle, and siphons.

PLATE III.

FIG. 3. Ditto with left valve of shell raised backward. Shows inside of left shell and outside of left mantle fold. Foot and siphons retracted.

FIG. 4. *Mya arenaria*, with mantle split from base of siphons ventro-medially to above anterior end and left half raised upward, to show contents of branchial cavity.

PLATE IV.

FIG. 5. *Mya arenaria.* Natural size. Left shell, mantle, siphon walls and gills taken off. Also left walls of kidney, pericardium, and abdomen removed, and the contents of the latter dissected down to the intestine and crystalline style, to show their course.

F S—foot-slit, through mantle.
F—foot.
P G—pedal ganglion.
C S—crystalline style.
I—intestine.
G G—genital gland.
Ab—abdomen.
BC—branchial cavity.
B—branchiæ, right side.
RS—retractor muscle of siphons, showing through the right wall of the mantle.
M—mantle, split ventral wall.
S—shell.
VS—ventral siphon.
Mo—mouth.
CG—cerebral ganglion.
St—stomach.
L—liver.
PG—position of pericardial gland.
P—pericardium.
U—umbo.
V—ventricle.
K—kidney.
VG—visceral ganglion.
PA—posterior adductor muscle.
A—anus.
PS—partition between siphons.
DS—dorsal siphon.
AA—anterior adductor muscle.

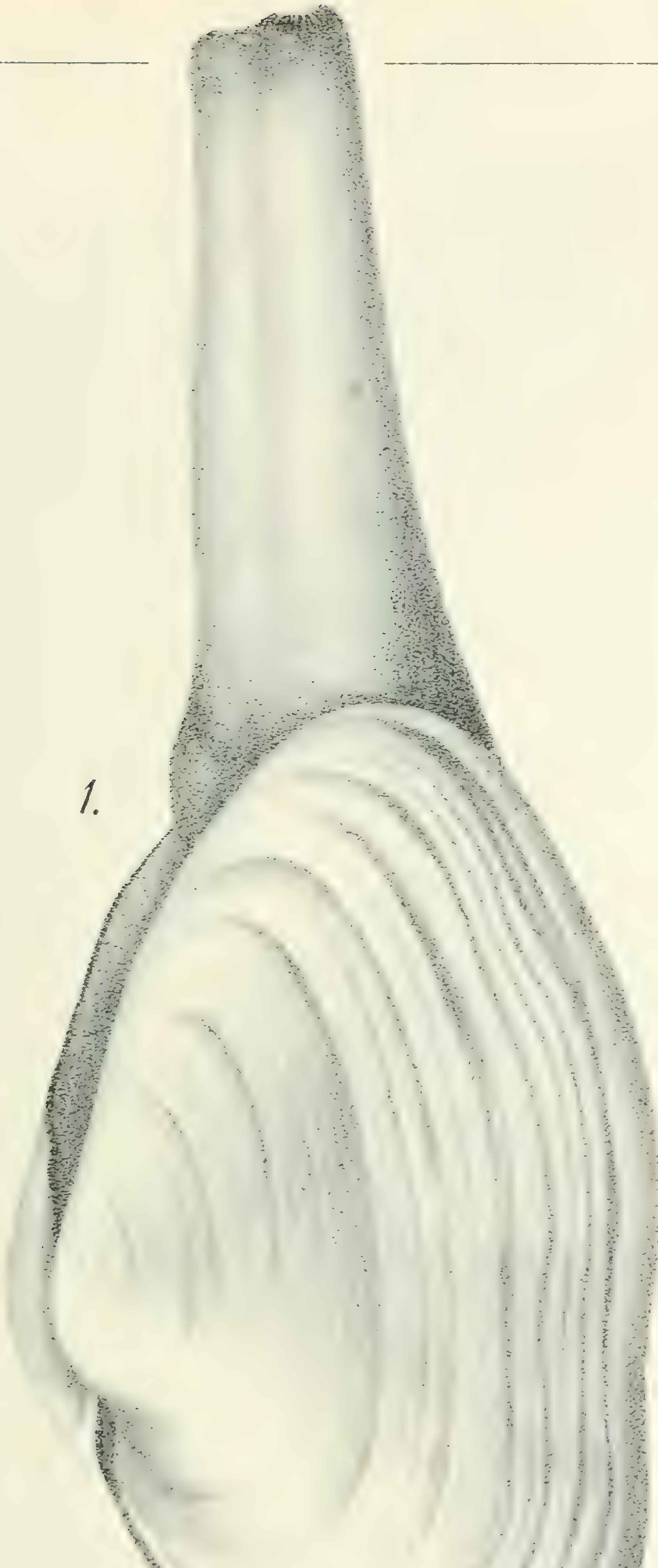
FIG. 6. *Nervous System* of Mya arenaria, from Rawitz, reduced.

FIG. 7. *Ovum* and *Spermatozoon* of Modiola modiolus, highly magnified.

FIG. 8. *Larva* of Mya arenaria, showing shells, velum with cilia, &c., from Mead, magnified.

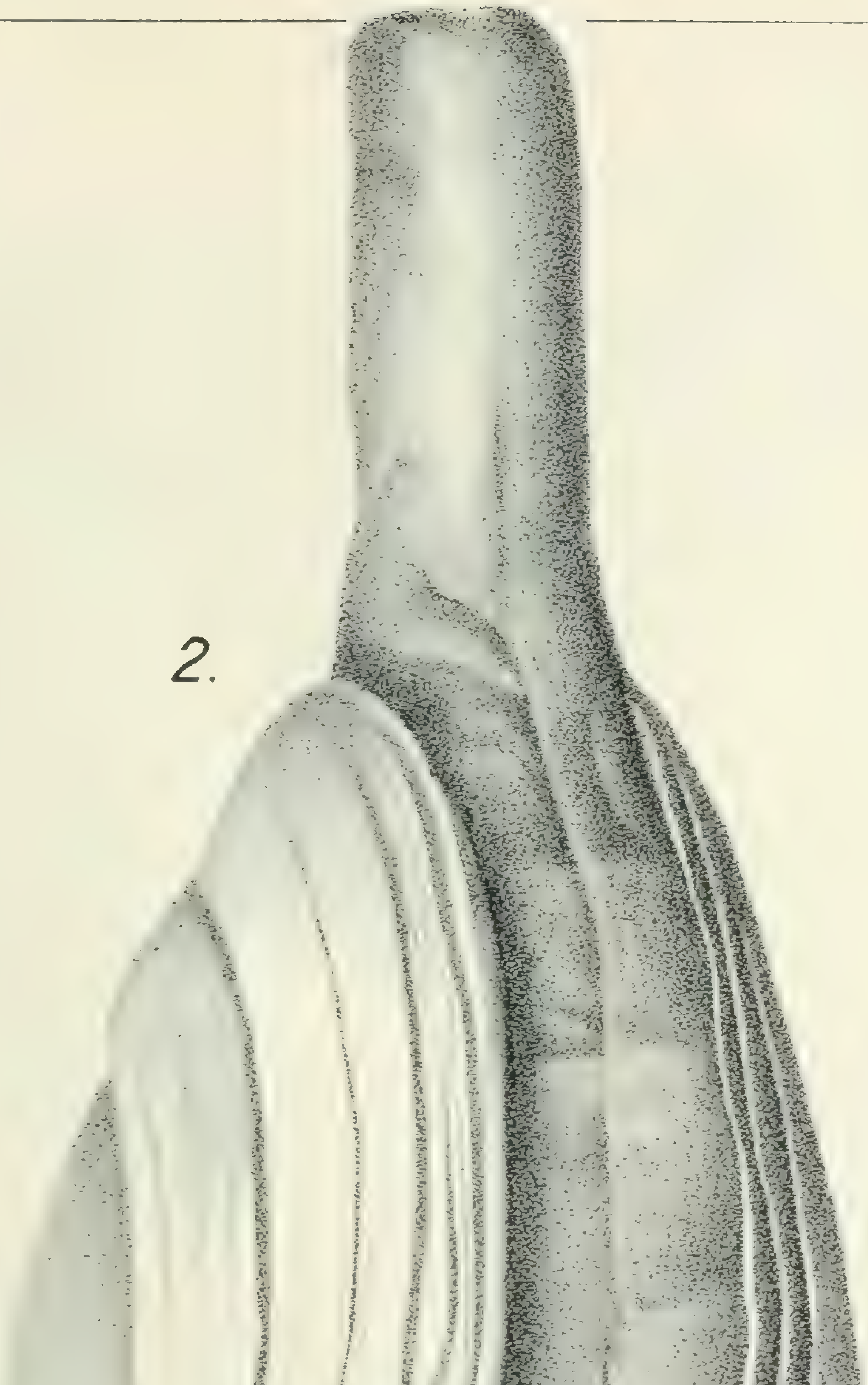
FIG. 9. Plant-food of clam. The first three are *diatoms*, the second three different aspects of *filamentous algæ*, the crescent shaped one is a *desmid*, and the spherical one the *egg of Fucus.* Highly magnified. These illustrate only a few of the commonest forms from the intestine of the clam.

FIG. 10. "*Clam Hoe*," reduced.



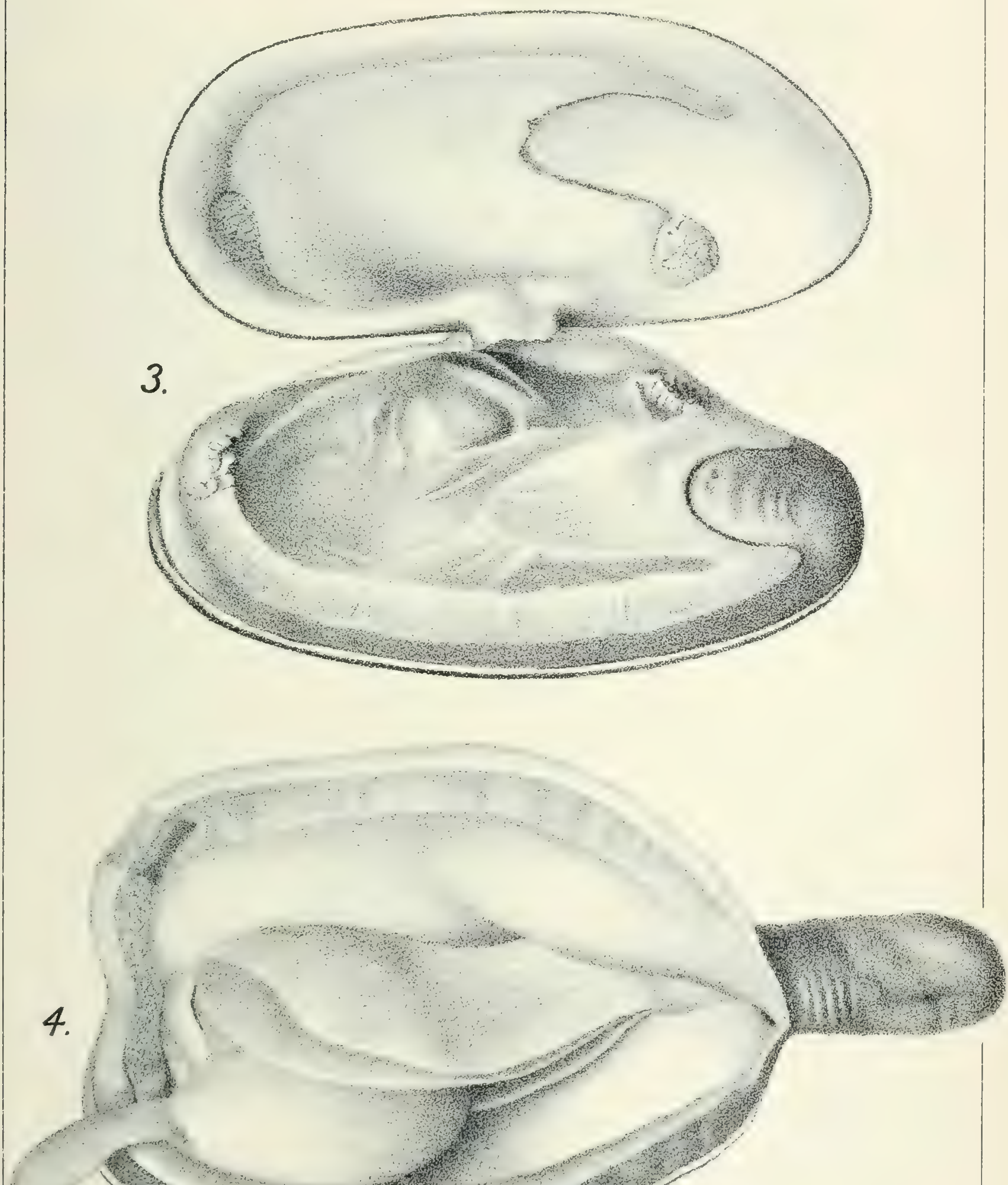
1.

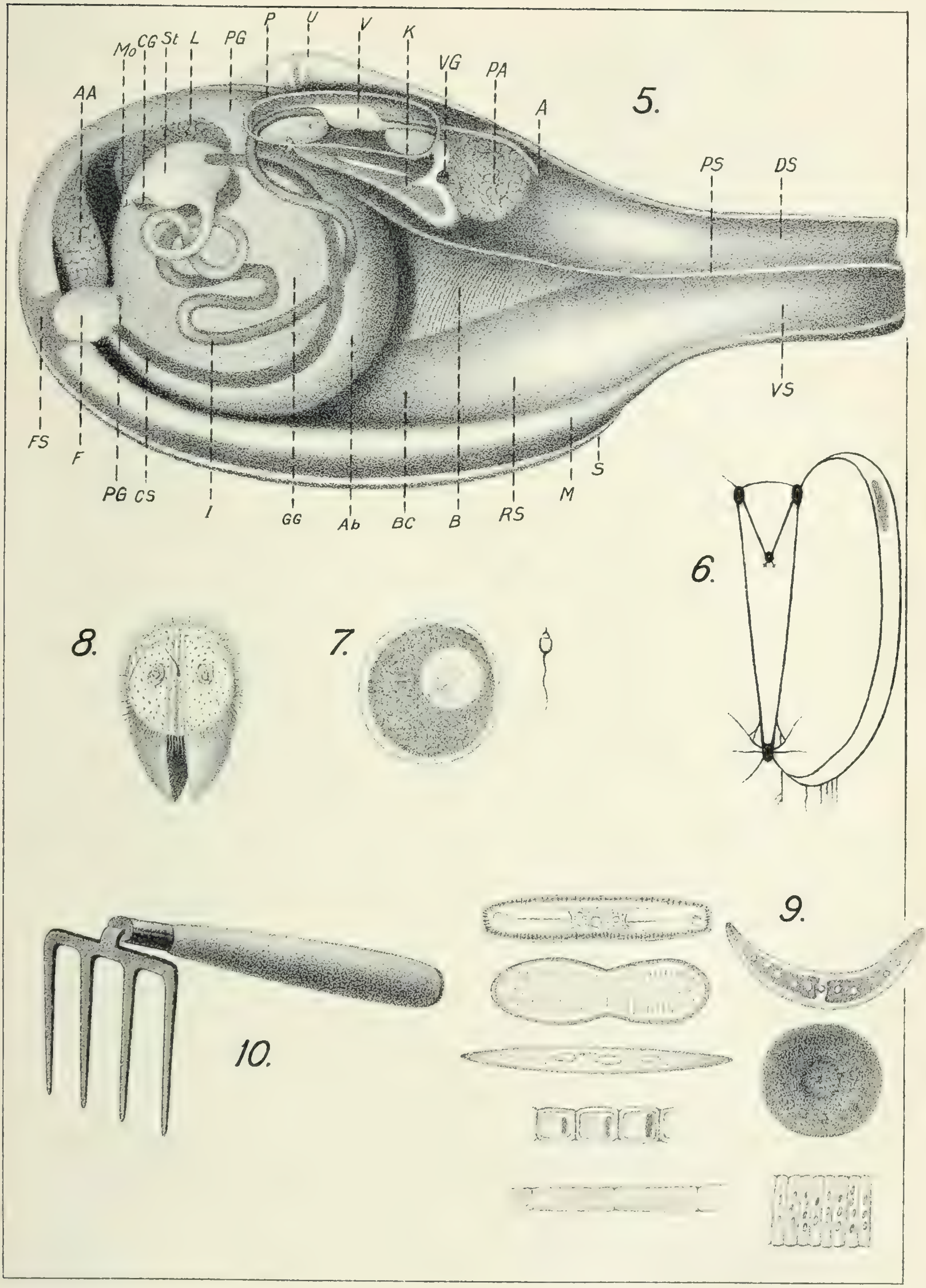
2.



3.

4.




5.
AA
Mo
CG
St
L
PG
P
U
V
K
VG
PA
A
PS
DS
VS
FS
F
PG
CS
I
GG
Ab
BC
B
RS
M
S
6.
8.
7.
9.
10.

IV

REPORT ON THE FLORA OF ST. ANDREWS, N.B.

BY PROFESSOR JAMES FOWLER, LL. D., QUEEN'S UNIVERSITY, KINGSTON.

INTRODUCTORY NOTES.

On June 9, 1900, the writer arrived at the Biological Laboratory, at St. Andrews, and devoted his time till August 18, to the study of the flora in the neighbourhood, and to the collection of herbarium specimens. The special object of his visit was to collect and study the marine algæ that might be found in that part of the Bay of Fundy. At the time of his arrival the retreating tide had left the rugged shore bare for a considerable distance, and the rocks, covered with a dense growth of rock-weed (Fucus) presented an attractive field for exploration. After spending a couple of days among the slippery rocks and mud, he discovered that very few species of algæ could be secured, and only those of the most hardy species. The rugged character of the shores, formed by the waves and tides from the red sandstone in some localities, and from volcanic rock in others, renders it impossible to travel along the beach any considerable distance in search of specimens. The aid of a boat is indispensable to the collector who wishes to extend his researches beyond the immediate neighbourhood of the station; but unfortunately the writer was precluded from more extended investigations. Disappointed at the small number of species where the prospects seemed so bright, he endeavoured to discover the reasons of their paucity, and is of the opinion that the following facts explain the phenomenon :—

1. The great tides of the Bay of Fundy produce currents which sweep away all plants not firmly anchored to the rocks. The fucaceæ, possessed of tough and flexible stems, and attached to the rocks by holdfasts that cannot be separated from them by any force tugging at the stems and branches, are naturally adapted to resist the action of waves and currents, while other more delicate species are swept away and carried out to sea or thrown up on the rocky shores.

2. At low water, a large extent of shore is left bare, and the algæ attached to the rocks are exposed for several hours every day to the warm winds and drying power of the summer sun. All plants unable to endure this ordeal must give place to the hardier species. The delicate forms that inhabit the pools or marshy shores are consequently unknown.

3. The great rise and fall of the tides stir up the waters of the bay to a great depth and as no broad areas of sand are exposed to the sun's rays to absorb heat and impart it to the waters that cover them at the return of the tide, these waters are always cold. Hence only algæ capable of flourishing in the cold waters are adapted to these rugged shores.

The combination of these factors constitutes an environment which is fatal to all but the most hardy species of littoral algæ. All delicate forms must betake themselves to retired creeks and sheltered inlets where many of them may doubtless be found; but they can only be reached by the collector who is fortunate enough to enjoy the advantage of appropriate transit by water.

Having failed, owing to the causes mentioned above, and the lack of necessary facilities for identifying species, to secure the number of marine plants anticipated, the

collector immediately turned to the streets and fields of the town and its neighbourhood which promised a more abundant harvest. During the early half of the century St. Andrews was distinguished for its great commercial activity, especially in its export of lumber. The long line of wharfs and the numerous warehouses, now falling into ruins, along the front of the town, are monuments of a prosperity which has now completely passed away with the destruction of the forests upon which it depended. Some of the streets as well as the wharfs are now almost deserted, and furnish favourable conditions for the growth and propagation of the foreign weeds and plants imported in earlier days. Many gardens and fields have been abandoned by their owners and are now rich collecting grounds for the botanist. Plants that once ornamented the grounds of wealthy merchants or prosperous farmers, have spread to the roadside and fields, or abound on the sidewalks along the deserted streets. A large area near the town, which once constituted the town park, with its winding paths, its artificial lake and its pleasant flower beds and grass plots, is now a perfect paradise for the botanist.

The writer can recall no locality he has ever visited where such a large number of foreign plants can be found in such a limited area. At the time of his arrival the early blooming plants had shed their flowers. The forest trees and native shrubs had passed the flowering season—had assumed their summer appearance and were now ripening their fruits. The winds were scattering the seeds of the poplars and willows over the neighbourhood where they grew. But though the spring flowers had disappeared the streets and fields were gay with the blossoms of foreign plants. Every rising sun was welcomed with a fresh display of floral beauty.

For several weeks *Ranunculus repens*, L., whether native or introduced, displayed its large yellow flowers abundantly in the ditches along the streets and in the damp grounds ; and the common Buttercup (*Ranunculus acris*, L.) adorned the higher grounds. The Wild Mustard (*Brassica arvensis*, L.) has pushed its way successfully out into the open country and many fields were brilliant with its yellow petals. Two other species (*Brassica nigra*, Koch. and *B. campestris*, L.) occupied more limited areas, but added to the general display. Another member of the Cruciferous family (*Lepidium ruderale*, L.) found a congenial home on the decaying wharfs. Among the introduced forms, which have secured a permanent home for themselves, few have become more conspicuous than the yellow clover (*Trifolium procumbens*, L.) It has spread over roads and railroad tracks in different localities to the almost total exclusion of the other species. It must, however, yield the palm to the Carroway (*Carum carui*, L.) which has not only invaded the town but has overrun the entire country for miles around. If the seeds were collected a sufficient quantity would be obtained to supply the demands of the province, perhaps of the Dominion. Of thirty-two species of Compositæ collected, twenty have been introduced from foreign lands. The less frequented streets were brilliant during the month of June with Dandelions of which two species occur (*Taraxacum taraxacum*, Karst, and *T. erythrospermum*, Andrz). The latter must be rare as the writer has never noticed it elsewhere. One of the most interesting members of this family is the *Hieracium aurantiacum*, L., which is exceedingly abundant near the laboratory, but has not spread into the fields. *Leontodon autumnalis*, L., meets the eye everywhere, and *Tragopogon pratensis* is common in deserted gardens and fields. The Blue-bell family (Campanulaceæ) is represented by large numbers of *Campanula rapunculoides*, L., whose long racemes of blue flowers with corollas an inch in length are very conspicuous on the sidewalks and along the garden fences.

Of the native plants in the immediate neighbourhood of the laboratory in the months of June and July the following species are most likely to attract the attention of the visitor from the west :—

Viola primulaefolia, L.
Viola lanceolata, L.
Potentilla tridentata, Ait.
Potentilla anserina, L.
Rosa humilis lucida, Ehrh.
Drosera rotundifolia, L.
Aster tardiflorus, L.
Antennaria neodioica, Greene.
Rhodora Canadensis, L.
Euphrasia Americana.
Rhinanthus Crista-Galli, L.
Carex Goodenovii, J. Gay.
Carex maritima, Muller.
Poa flava, L.
Festuca ovina duriuscula, L.
Botrychium simplex, Hitchcock.

The following probably mark the sites of former gardens:—

Tilia Europœa, L.
Geranium pratense, L.
Æsculus hippocastanum, L.
Acer platanoides, L.
Acer pseudo-platanus, L.
Robinia pseudacacia, L.
Caragana arborescens, Lam.
Spiraea sorbifolia, L.
Spiraea ulmaria, L.
Crataegus oxyacantha, L.
Philadelphus coronarius, L.
Sedum acre, L.
Diervilla florida, Sieb. & Zucc.
Centaurea nigra, L.
Syringa vulgaris, L.
Leptandra Virginica, Nutt.
Euphorbia Cyparissias, L.
Ulmus campestris, L.
Larix Europaea, D.C.
Hemerocallis fulva, L.
Lysimachia nummularia, L.

BOTANICAL LIST.

List of plants collected at St. Andrews, N.B., between June 9 and August 18, 1900.

NOTE—The Nomenclature follows that of Brown & Britton, *Illustrated Flora.*

ORDER I. RANUNCULACEÆ.

Genera.	Spec.	
1	1	Thalictrum polygamum, Muhl.
2	2	Ranunculus repens, L.
	3	Ranunculus acris, L.
3	4	Oxygraphis Cymbalaria, Prantl.
4	5	Coptis trifolia, Salisb.
5	6	Actaea rubra, Willd.

ORDER II. NYMPHAEACEÆ.

6	7	Castalia odorata, Woodv.
7	8	Nymphaea advena, Soland.

ORDER III. CRUCIFERÆ.

8	9	Barbarea barbarea, MacM.
9	10	Erysimum cheiranthoides, L.
10	11	Brassica arvensis, L.
	12	Brassica nigra, Ksch.
	13	Brassica campestris, L.
11	14	Bursa bursa-pastoris, Britton.
12	15	Lepidium ruderale, L.
13	16	Cakile edentula, Hook.
14	17	Raphanus raphanistrum, L.

ORDER IV. VIOLACEÆ.

15	18	Viola obliqua, Hill.
	19	Viola blanda, Willd.
	20	Viola primulaefolia, L.
	21	Viola lanceolata, L.

ORDER V. CARYOPHYLLACEÆ.

16	22	Moehringia lateriflora, L.
17	23	Alsine media, L.
	24	Alsine longifolia, Britton.
	25	Alsine graminea, Britton.
	26	Alsine humifusa, Britton.
18	27	Cerastium vulgatum, L.
19	28	Sagina procumbens, L.
20	29	Tissa rubra, Britton.
	30	Tissa Canadensis, Britton.
21	31	Spergula arvensis, L.

ORDER VI. HYPERICACEÆ.

22	32	Hypericum perforatum, L.
	33	Hypericum mutilum, L.
	34	Hypericum Canadense, L.

ORDER VII. TILIACEÆ.

23	35	Tilia Americana, L.
	36	Tilia Europaea, L.

ORDER VIII. GERANICADÆ.

Genera.	Species.		Genera.	Species.	
24	37	Geranium pratense, L.		36	Oxalis stricta, L.
25	38	Oxalis acetosella, L.	26	40	Impatiens biflora, Walt.

ORDER IX. ILICINEÆ.

27	41	Ilex verticillata, Gray.

ORDER X. SAPINDACEÆ.

28	42	Æsculus Hippocastanum, L.		44	Acer platanoides, L.
29	43	Acer spicatum, Lam.		45	Acer pseudo-platanus, L.

ORDER XI. LEGUMINOSÆ.

30	46	Trifolium pratense, L.	33	52	Robinia pseudacacia, L.
	47	Trifolium repens, L.	34	53	Vicia cracca, L.
	48	Trifolium procumbens, L.	35	54	Lathyrus maritimus, Bigel.
31	49	Melilotus officinalis, Willd.		55	Lathyrus palustris, L.
	50	Melilotus alba, Lam.	36	56	Caragana arborescens, Lam.
32	51	Medicago lupulina, L.			

ORDER XII. ROSACEÆ.

37	57	Prunus virginiana, L.		68	Potentilla argentea, L.
38	58	Spiræa salicifolia, L.		69	Potentilla tridentata, Ait.
	59	Spiræa tomentosa, L.		70	Potentilla anserina, L.
	60	Spiræa sorbifolia, L.		71	Potentilla Canadensis, L.
	61	Spiræa ulmaria, L.	43	72	Comarum palustre, L.
39	62	Rubus Americanus, Britton.	44	73	Rosa humilis lucida, Best.
	63	Rubus strigosus, Miche.	45	74	Cratægus oxyacantha, L.
	64	Rubus villosus frondosus, Bigel.	46	75	Aronia nigra, Britton.
40	65	Geum strictum, Ait.	47	76	Sorbus Americana, Marsh.
41	66	Fragaria virginiana, Mill.		77	Sorbus sambucifolia, Roem.
42	67	Potentilla norvegica, L.			

ORDER XIII.—SAXIFRAGACEÆ.

48	78	Philadelphus coronarius, L.	49	79	Ribes oxyacanthoides, L.

ORDER XIV.—CRASSULACEÆ.

50	80	Sedum acre, L.

ORDER XV.—DROSERACEÆ.

51	81	Drosera rotundifolia, L.

ORDER XVI.—HALORAGEÆ.

52	82	Callitriche palustris, L.

ORDER XVII.—ONAGRACEÆ.

53	83	Chamænerion angustifolium, Scop.	55	87	Onagra biennis, Scop.
54	84	Epilobium lineare, Muhl.	56	88	Kneiffia pumila, Spach.
	85	Epilobium coloratum, Muhl.	57	89	Circæa alpina, L.
	86	Epilobium adenocaulon, Haussk.			

ORDER XVIII.—UMBIFELLIFERÆ.

Genera.	Species.	
58	90	Carum carui, L.
59	91	Cicuta bulbifera, L.
60	92	Hydrocotyle Americana, L.
61	93	Ligusticum Scoticum, L.

ORDER XIX.—ARALIACEÆ.

62	94	Aralia hispida, Vent.
	95	Aralia nudicaulis, L.

ORDER XX.—CORNACEÆ.

63	96	Cornus Canadensis, L.

ORDER XXI.—CAPRIFOLIACEÆ.

64	97	Viburnum cassinoides, L.
65	98	Linnæa borealis, L.
66	99	Diervilla Diervilla, MacM.
	100	Diervilla florida, Sieb. & Zucc.

ORDER XXII.—RUBIACEÆ.

67	101	Houstonia coerulea, L.

ORDER XXIII.—COMPOSITÆ.

68	102	Eupatorium perfoliatum, L.
69	103	Solidago puberula, Nutt.
	104	Solidago juncea, Ait.
	105	Solidago rugosa, Mill.
	106	Solidago Canadensis, L.
70	107	Euthamia graminifolia, Nutt.
71	108	Aster tardiflorus, L.
	109	Aster lateriflorus, Britton.
80	118	Achilea millefolium, L.
81	119	Chrysanthemum leucanthemum, L.
82	120	Artemisia vulgaris, L.
83	121	Senecio vulgaris, L.
84	122	Antennaria neodioica, Greene.
85	123	Arctium minus, Schk.
86	124	Carduus arvensis, Robs.
87	125	Centaurea nigra, L.
72	110	Doellingeria umbellata, Nees.
73	111	Leptilon Canadense, Britton.
74	112	Erigeron ramosus, B. S. P.
75	113	Anaphalis margaritacea, Benth. & Hook
76	114	Gnaphalium uliginosum, L.
77	115	Ambrosia artemisiæfolia, L.
78	116	Rudbeckia hirta, L.
79	117	Anthemis cotula, D. C.
88	126	Tragopogon pratensis, L.
89	127	Leontodon autumnalis, L.
90	128	Hieracium aurantiacum, L.
91	129	Taraxacum taraxacum, Karst.
	130	Taraxacum erythrospermum, Audrz.
92	131	Sonchus oleraceus, L.
	132	Sonchus asper, Vill.
	133	Sonchus arvensis, L.

ORDER XXIV. LOBELIACEÆ.

93	134	Lobelia inflata, L.
	138	Lobelia Dortmanna, L.

ORDER XXV. CAMPANULACEÆ.

94	136	Campanula rapunculoides, L.
	137	Campanula rotundifolia, L.

ORDER XXVI. ERICACEÆ.

95	138	Vaccinium Pennsylvanicum, Lam.
	139	Vaccinium Canadense, Richards.
	140	Vaccinium vitis-idæa, L.
96	141	Oxycoccus macrocarpus, Pers.
97	142	Kalmia angustifolia, L.
98	143	Rhodora Canadensis, L.
99	144	Ledum Grœnlandicum, Œder.
100	145	Pyrola elliptica, Nutt.
101	146	Monotropa uniflora, L.

ORDER XXVII. PLUMBAGINACEÆ.

102	147	Limonium Carolinianum, Britton.

ORDER XXVIII. PRIMULACEÆ.

103	148	Trientalis Americana, Pursh.
104	149	Lysimachia terrestris, B.S.P.
	150	Lysimachia nummularia, L.
105	151	Glaux maritima, L.

ORDER XXIX. OLEACEÆ.

106	152	Fraxinus nigra, Marsh.
107	153	Syringa Persica, L.

ORDER XXX. GENTIANACEÆ.

Genera. Species. Genera. Species.

108 154 Menyanthes trifoliata, L.

ORDER XXXI. BORAGINACEÆ.

109 155 Myosotis arvensis, Hoffm.
110 156 Lappula Lappula, Karst.
111 157 Pneumaria maritima, Hill.

ORDER XXXII. CONVOLVULACEÆ.

112 158 Convolvulus sepium, L.

ORDER XXXIII. SCROPHULARIACEÆ.

113 159 Linaria linaria, Karst.
114 160 Chelone glabra, L.
115 161 Leptandra Virginica, Nutt.
116 162 Veronica scutellat, L
117 163 Euphrasia Americana, Wettst.
118 164 Rhinanthus Crista-Galli, L.

ORDER XXXIV. LABIATÆ.

119 165 Mentha sativa, L.
166 Mentha Canadensis, L.
120 167 Lycopus Americanus, Muhl.
121 168 Scutellaria galericulata, L.
122 169 Prunella vulgaris, L.
123 170 Galeopsis tetrahit, L.
124 171 Stachys palustris, L.
125 172 Glecoma hederacea, L.

ORDER XXXV. PLANTAGENACEÆ.

126 173 Plantago major, L.
174 Plantago maritima, L.

ORDER XXXVI. CHENOPODIACEÆ.

127 175 Atriplex hastata, L.
128 176 Salicornia herbacea, L.
129 177 Dondia Americana, Britton.

ORDER XXXVII. POLYGONACEÆ.

130 178 Rumex Brittanica, L.
179 Rumex acetosella, L.
131 180 Polygonum aviculare, L.
181 Polygonum erectum, L.
182 Polygonum Persicaria, L.
183 Polygonum sagittatum, L.
184 Polygonum convolvulus, L.

ORDER XXXVIII. EUPHORBIACEÆ.

132 185 Euphorbia Cyparissias, L.

ORDER XXXIX. URTICACEÆ.

133 186 Ulmus campestris, L.

ORDER XL. MYRICACEÆ.

134 187 Myrica gale, L.

ORDER XLI. CUPULIFERÆ.

135 188 Betula lutea, L.
189 Betula populifolia, Ait.
136 190 Alnus alnobetula, Koch
191 Alnus incana, Willd.

ORDER XLII. SALICACEÆ.

137 192 Salix lucida, Muhl.
193 Salix Bebbiana, Sarg.
194 Salix balsamifera, Barratt.

ORDER XLIII. CONIFERÆ.

138 195 Larix laricina, Koch.
196 Larix Europæa, DC.
139 197 Thuya occidentalis, L.
140 198 Juniperus nana, Willd.
199 Juniperus Sabina, L.

ORDER XLIV. ORCHIDACEÆ.

Genera.	Species.		Genera.	Species.	
141	200	Achroanthes unifolia, Raf.	144	203	Gyrostachys Romanzoffiana, MacM.
142	201	Leptorchis Loeselii, MacM.	145	204	Pogonia ophioglossoides, Nutt.
143	202	Corallorhiza multiflora, Nutt.	146	205	Habenaria hyperborea, R. Br.

ORDER XLV. IRIDACEÆ.

147	206	Iris versicolor, L.	148	207	Sisyrinchium angustifolium, Mill.

ORDER XLVI. LILIACEÆ.

149	208	Hemerocallis fulva, L.	151	210	Unifolium Canadense, Greene.
150	209	Vagnea stellata, Morong.	152	211	Steptopus roseus, Michx.

ORDER XLVII. JUNCACEÆ.

153	212	Juncus effusus, L.		216	Juncus articulatus, L.
	213	Juncus Balticus, Willd.		217	Juncus Canadensis brevicaudatus, Engelm.
	214	Juncus Gerardi, Loisel.			
	215	Juncus bufonius, L.	154	218	Juncoides campestre, Kuntze.

ORDER XLVIII. TYPHACEÆ.

155	219	Typha latifolia, L.

ORDER XLIX. ALISMACEÆ.

156	220	Sagittaria latifolia, Willd.

ORDER L. NAIADACEÆ.

157	221	Triglochin maritima, L.	159	223	Zostera marina, L.
158	222	Potamogeton Nuttallii, Cham. & Sch.			

ORDER LI. CYPERACEÆ.

160	224	Eleocharis ovata, R. Br.		239	Carex Goodenovii, J. Gay.
	225	Eleocharis palustris glaucescens, Gray.		240	Carex intumescens, Rudge.
	226	Eleocharis tenuis, Schutes.		241	Carex lurida, Wahl.
161	227	Scirpus microcarpus, Presl.		242	Carex maritima, Muller.
	228	Scirpus atrovirens, Muhl.		243	Carex Novæ-Angliæ, Schwein.
	229	Scirpus fluviatilis, Gray.		244	Carex pallescens, L.
	230	Scirpus cyperinus, L.		245	Carex pedicellata, Britton.
	231	Scirpus Americanus, Pers.		246	Carex scoparia, Schk.
162	232	Eriophorum Virginicum, L.		247	Carex sterilis, Willd.
163	233	Carex arctata, Boot.		248	Carex sterilis cephalantha, Bailey.
	234	Carex aurea, Nutt.		249	Carex stipata, Muhl.
	235	Carex brunnescens gracilior, Britton.		250	Carex tenera, Dewey.
	236	Carex canescens, L.		251	Carex tenuis, Rudge.
	237	Carex crinita, Lam.		252	Carex retrorsa, Schwein.
	238	Carex flava, L.		253	Carex viridula, Michx.

ORDER LII.—GRAMINEÆ.

164	254	Spartina cynosuroides, Willd.		267	Poa pratensis, L.
	255	Spartina patens, Muhl.		268	Poa trivialis, L.
	256	Spartina stricta maritima, Scrib.	172	269	Panicularia Canadensis, Kuntze.
165	257	Panicum implicatum, Scrib.		270	Panicularia nervata, Kuntze.
166	259	Anthoxanthum odoratum, L.		271	Panicularia Americana, MacM.
167	260	Phleum pratense, L.	173	272	Puccinella maritima, Parl.
168	261	Alopecurus geniculatus, L.	174	273	Dactylis glomerata, L.
169	262	Agrostis alba, L.	175	274	Festuca ovina duriuscula, L.
	263	Agrostis hyemalis, B.S.P.		275	Festuca elatior, L.
170	264	Danthonia spicata, Beauv.	176	276	Agropyron repens, L.
171	265	Poa compressa, L.	177	277	Hordeum jubatum L.
	266	Poa flava, L.	178	278	Elymus arenarius, L.

ORDER LIII.—EQUISETACEÆ.

179	279	Equisetum arvense, L.		280	Equisetum sylvaticum, L.

Order LIV.—Filices.

Genera.	Species.	
180	281	Polypodium vulgare, L.
181	282	Pteris aquilina, L.
182	283	Asplenium filix-foemina, Bernh.
183	284	Phegopteris Phegopteris, Underw.
	285	Phegopteris dryopteris, Fee.
184	286	Dryopteris spinulosa intermedia, Und.
	287	Dryopteris spinulosa dilatata, Underw.
	288	Dryopteris cristata, Gray.
	289	Dryopteris acrostichoides, Sw.
185	290	Onoclea sensibilis, L.
186	291	Woodsia ilvensis, R. Br.
187	292	Dicksonia punctilobula, Gray.
188	293	Osmunda Claytoniana, L.
	294	Osmunda cinnamomea, L.

Order LV.—Ophioglossaceæ.

189	295	Botrychium simplex, Hitch.
	296	Botrychium ternatum, Sw.

Order LVI.—Lycopodiaceæ.

190	297	Lycopodium lucidulum, Michx.
	298	Lycopodium obscurum, L.
	299	Lycopodium complanatum, L.

MUSCI.

Order LVII.—Sphagnaceæ.

191	300	Sphagnum acutifolium, Ehrh.
	301	Sphagnum cymbifolium, Ehrh.

Order LVIII.—Bryaceæ.

192	302	Leucobryum glaucum, L.
193	302	Ceratodon purpureus, L.
194	303	Ulota crispa, Brid.
	304	Ulota crispula, Brid.
	305	Ulota Ludwigii, Brid.
195	306	Polytrichum commune, L.
	307	Polytrichum juniperinum, Willd.
196	308	Webera nutans (Schreb.) Hedw.
197	309	Pylaisia Schimperi, Card.
198	310	Aulacomnium palustre. Schwaegr.
199	311	Hypnum uncinatum, Hedw.

Order LIX.—Jungermanniaceæ.

200	312	Ptilidium ciliare, Nees.

LICHENES.

201	313	Alectoria jubata, L.
202	314	Usnea barbata, L.
203	315	Theloschistes parietinus, L.
204	316	Sticta pulmoraria, L.
205	317	Peltigera aphthosa, Hoffm.
206	318	Cladonia rangiferina, L.
	319	Cladonia cristatella, Tuck.

ALGÆ.

207	320	Fucus vesiculosus, L.
	321	Fucus nodosus, L.
208	322	Laminaria longicruris, De la Pyl.
209	323	Chordaria flagelliformis, Ag.
210	324	Polysiphonia fastigiata, Grev.
211	325	Corallina officinalis, L.
212	326	Rhodymenia palmata, Grev.
213	327	Porphyra vulgaris, Ag.
214	328	Enteromorpha compressa, Grev.
215	329	Ulva linza, L.
	330	Ulva latissima, L.
216	331	Gigartina mamillosa, Ag.

Several specimens of Algæ collected in addition to the foregoing have not yet been determined.

V

FOOD OF THE SEA-URCHIN (Strongylocentrotus dröbachiensis.)

BY Dr. F. H. SCOTT, Ph.D., PHYSIOLOGICAL LABORATORY, UNIVERSITY OF TORONTO.

The sea-urchin is one of the commonest animals on our Atlantic coast where great numbers are found in all suitable places. They prefer a gravelly or rocky bottom and are rarely found on mud or coarse sand. Just below the low tide mark on a gravelly beach, or better on a beach of medium-sized stones separated by patches of sand, the sea-urchins are exceedingly numerous. Another favourite resort of the sea-urchin is on the sides of bare rocks and reefs, where there are often thousands aggregated together. Many, especially small urchins, are found under stones on the bottoms of tide pools. Urchins frequently attach shells and other débris to themselves and in localities where such materials are abundant are often invisible owing to such a covering. In the deeper waters of Passamaquoddy Bay they are also abundant on suitable bottoms, for the dredge is often filled with them from depths of 12 to 15 fathoms.

The sea-urchin is more or less hemispherical in shape and is covered with movable spines. The spines are green in colour, nearly an inch long and are articulated to the shell or test by a ball and socket joint. The test, which after the removal of the spines has well been likened by Ganong [1] to an old-fashioned smooth doorknob, is made of twenty rows of hexagonal plates closely cemented together. Five double rows of these plates are perforated and alternate with similar imperforate rows. On the external surface of all the plates are little conical elevations which fit into depressions on the base of the spines forming the movable articulations. Scattered among the spines are other shorter appendages which end in minute pinchers (pedicellariæ). These probably assist the animals in grasping small objects.

Within the test among the other organs is the water vascular system. This system is peculiar to the Echinodermata and has the function of forcing water into the tube feet, or of withdrawing it from them. The tube feet, which project through the openings in the perforated plates of the test, are hollow cylinders capable of great extension. Each foot ends in a sucker and thus the animal by attaching its feet is enabled to adhere to different objects. When the water is forced in, the feet may extend away beyond the tips of the spines; but when the water is withdrawn the feet are much the shorter.

The tube feet are the principal means of locomotion, although the animal can move on its spines alone. By extending its feet on one side, attaching the suckers and then pulling, the animal can move in any definite direction along flat surfaces or ascend perpendicular ones. By this method, two sea-urchins, in a tide pool with a smooth rocky bottom, were observed to move six and seven inches respectively in two minutes. This is at the rate of about sixteen yards per hour and indicates that the urchins might move considerable distances during a tide period. Whether the urchins do move at every tide is another question. A few observations lead me to think that they do not move very much, but no experiments were made to decide this point.

The usual position of the animal is with the flat side of the hemisphere towards the ground. The central part of this side is membranous and devoid of spines. The mouth is situated in the centre of this membrane and has the tips of the five teeth projecting from it. Only the tips of the teeth project outside, the remainder along with a complicated apparatus for moving them being beneath the membrane. The œsophagus a longitudinally ribbed tube leads to the intestine, there being no stomach such as is

found in higher animals. The intestine coils completely round the test, turns and then winds back again to end finally in the anus which is situated on the pole of the shell opposite the mouth. The anus is surrounded by a specially modified plate of the test. One of these apical plates is very distinct as it is much larger than the others. This plate is perforated and through its fine pores the water vascular system is brought into communication with the outside.

The food in the digestive tract is surrounded by a mucinous secretion but such secretion is never copious. In the secretion are ferments which resemble those found in the pancreatic juice of mammals in that they act in neutral or alkaline media but not in acid ones. There is a diastatic ferment present which, however, acts slowly on raw starch. There is also a proteolytic ferment present and probably a steatolytic one but the tests for the latter were not conclusive. The ferments present retain their hydrolytic activity through a long range of temperatures being active from near the freezing point to 55° C.

In the investigation of the food the contents of the digestive tracts of more than 300 urchins were examined. Most of these were from the littoral fauna in the immediate neighbourhood of St. Andrews, N.B., but some were obtained from L'Etang Harbour and others from Deer, Indian and Dochet Islands. Besides these collected in shallow water others were obtained by the dredge from different parts at different depths of Passamaquoddy Bay. In the case of the littoral ones the procedure was to go at low water, carefully note the surroundings of the urchins, break through the test and examine the contents of their digestive tracts. Specimens were taken from each locality and the contents of their alimentary canal submitted to microscopical examination. Urchins were also kept in clean vessels and in this manner their excrements obtained. Dredged specimens were examined in a similar manner. An idea of their surroundings was obtained from the character of the remaining contents of the dredge.

The food, judged by the substances in their digestive tracts, varies with the local conditions under which the animals live. Such conditions were carefully studied in the case of the littoral urchins which are the ones the fishermen accuse of destroying the seaweed. It was found that the entire character of the food might change within a very short distance. In all cases where the urchins lived in close proximity to the large fucoid or laminarian seaweeds, there was practically nothing but pieces of such seaweed in their digestive tracts. The seaweed had been bitten in pieces a millimetre or two long, and had been changed from the ordinary brown to a green colour owing to the dissolution of its brown colouring matter. Urchins in these localities were frequently found with pieces of seaweed in their mouths. In cases where the urchins lived at a distance from the large seaweeds or where these were scarce, the digestive tracts contained little globular masses of sand. On breaking one of these masses and examining it under the microscope, the remains of the great variety of minute organisms which are common on the bottom, or which may be scraped from seemingly bare rocks are observed among the sand grains. The great bulk of these remains are those of microscopic plants belonging chiefly to the Diatomaceæ but other minute Algæ are also common. The animals found in these masses are chiefly Radiolaria and other Protozoa, but occasionally other minute animals, including larvæ, are noticed. In a few cases carrion was observed in the alimentary canal. Dead animals placed in the water are soon covered with urchins which rapidly devour them. In lobster traps it is common to find considerable numbers of urchins which are attracted, no doubt, by the dead animal matter used as bait. Although carrion is soon found and devoured by the urchins it cannot be considered one of their ordinary foods because its supply is erratic and uncertain.

An examination of the excrements of the animal confirmed what was observed in the intestinal canal. When the urchins were obtained near seaweed, the excrements were small pieces of seaweed which did not seem greatly altered by their passage through the intestinal canal, except in their colour. When the urchins came from localities remote from seaweed, the excrements were the small globular masses such as are observed in the alimentary tract. In tide pools where sea-urchins are abundant, the bottom is frequently covered with a layer of the castings of these animals.

The sea-urchin has thus two principal foods which we may call seaweed and surface sand. The seaweed is cut into little pieces, whilst the sand with all the minute organisms

it contains is formed into little masses—the mucinous secretion of the digestive tract holding the grains together. It is usual to find both of these foods in the alimentary canal of our urchins, although one of them may be so abundant that the quantity of the other is insignificant. As stated, when the urchins live in proximity to the large seaweeds, it is usual to find seaweed almost exclusively in their intestines. It is not uncommon, however, to find a little surface sand, and in a few cases this may form a considerable part of the total content. Thus from one locality where seaweed was abundant, forty-five urchins were taken and examined. In twenty of these there was nothing but seaweed; in twenty-two others there was over 95 per cent of seaweed and less than five per cent of surface sand. In the remaining three the percentage of surface sand was somewhat larger. Where the large seaweeds are not abundant, yet not scarce, the urchins usually had about equal quantities of seaweed and surface sand in their digestive tracts. Sometimes, however, urchins were found with practically all seaweed or all surface sand in their intestines. Even in cases where the urchins were some distance from the large seaweed, one was occasionally found which had eaten a considerable amount of seaweed. Such seaweed is, I think, carried to the urchins by the tides after the waves have torn it from the rocks. In only a few cases was seaweed observed in the intestines of the urchins which had been dredged in the deeper waters of the bay. In their case, as in the case of urchins living on rocks devoid of seaweed, the digestive tract contained chiefly the globular masses of surface sand. Thus there is no doubt that the sea-urchin is, in chief, a vegetarian, although it does eat carrion at every opportunity.

These observations agree with what is known concerning the food of sea-urchins on the British coast. Sea-urchins have long been known to eat seaweed, for in 1838 Sharpey [2] observed the two kinds of food, but considered the surface sand merely as the excrements. He says 'The Echini (sea-urchins) are generally believed to feed on mollusca and crustacea, and in corroboration of this, Tiedemann states that he has found in the *Echinus sexatilis* small univalve and bivalve shells entire among the excrements, besides fragments of larger ones. Blainville, on the other hand, could never find anything else than sand in the alimentary canal, and he remarks that the general opinion as to the carnivorous habits of the sea-urchin is probably more of an inference from the structure of the teeth and jaws than the results of observations; he, however, adds that M. Bosc had witnessed an echinus in the act of seizing and devouring a small crustaceous animal. In the intestine of the *E. esculentus* we have usually found numerous small portions of seaweed, for the most part encrusted with *Flustra.* The excrements, which are in the form of small round pellets about the size of peppercorns, consist chiefly of sandy matter with fragments of shells, but it would be difficult to say whether these are the remains of digested mollusca or merely a portion of the usual testaceous débris so abundant in sand and mud.' In 1877, F. H. Butler [3] wrote, 'The food of the Echinidea consists either of seaweed and small shell-fish and crustaceans, which are conveyed to the mouth by the pedicels, or, as in the case of the edentulous forms, of sand and earth containing nutritive materials.' In 1878, Schmidt [4] wrote, 'They are exceedingly inactive, and appear to feed only on the seaweeds and tangs and the animals found on them.' Prof. MacBride, of McGill University, I may add, informed me that my observations agree with what he has observed on the British coast.

In the case of the urchins found on the North American coast, no one, so far as I could find, has published a detailed account of their food, or has even observed their two kinds of food. In 1867 Sir William Dawson [5] published an account of the food of our urchins. His specimens were obtained at Tadoussac, Que., but must have been from a locality remote from the large seaweeds for he found nothing but the surface sand. He writes: 'I found the intestine full of small round pellets, which proved to be made up of the minute confervoid sea-weeds that grow on submerged rocks, mixed with many diatoms and remains of small sponges. It would thus appear that the curious apparatus of jaws and teeth possessed by this creature is used in a kind of browsing or grazing process, by which it scrapes from the submarine rocks the more minute seaweeds which cling to them, and forms these into solid balls, which are swallowed, and in this state passed through the intestinal canal, where they may be found in all stages of digestion...... Though the sea-urchin is thus a vegetarian, yet near the fish-

ing stations it may often be seen to feed greedily on the garbage of the fisheries, but I have not known it to attack living animals.' Verrill [6] among other matters, deals with the food of this animal, but his specimens must have been dredged or taken from a part of the coast devoid of sea-weed for he found, like Sir William Dawson, the surface sand. He says, on page 406: 'The common green sea-urchin, *Strongylocentrotus dröbachiensis*, so very abundant further north, and especially in the Bay of Fundy, where it occurs in abundance at low water mark, and on rocky bottoms at all depths down to 110 fathoms, and off St. George's Bank even down to 450 fathoms, is comparatively rare in this region. It feeds partly on diatoms and other small algæ, &c., which it cuts from the rocks with the sharp points of its teeth, but it is also fond of dead fishes, which are soon devoured, bones and all, by it in the Bay of Fundy. In return it is swallowed whole in large quantities by the wolf fish and by other large fishes.' Packard [7] found sea-weed, but does not mention the surface sand. He says: 'It eats sea-weeds, and is also a scavenger, feeding on dead fish, &c. We have observed great numbers of them assembled in large groups, feeding on fish offal, a few fathoms below the surface, in a harbour on the coast of Labrador, where fishing vessels were anchored.' Although practically all who have investigated the food, have concluded that the urchins are herbivorous, there is, seemingly, among zoologists a general belief that they are carnivorous. This is probably due to the fact that other groups of Echinoderms are undoubtedly carnivorous, and that a dead animal covered with urchins, is of course a very conspicuous object and readily seen.

Admitting that sea-weed is the principal food of the sea-urchin, it is impossible that they could destroy enough of it, in any locality, to appreciably diminish the total quantity unless within a recent period there had been an abnormal increase of urchins in such district. Such an increase would be accounted for either by a decrease in the enemies of the urchins, or by an increase in their food supply. It is known from the observations of the British Fish Commission that sea-urchins are eaten by many large fish, but it is probable that the large fish eat the urchins found in deep water and do not approach those living in shallow water, which are the ones in which we are especially interested. Schiemenz [8] reports a case of an urchin being attacked and eaten by starfish, but such occurrences are rare. Fishermen report that in winter the urchins are eaten by crows and gulls, but the numbers destroyed in this way must be very small, because the urchins are uncovered only at spring tides. It cannot be an increase in the food supply which has caused an increase—if there really is an increase—in the number of urchins because the sea-weed (their food) is said to be decreasing. Though urchins, as will be shown, have been abundant on our coast for ages, there might be limited areas on which, for some unknown reason, there never have been many urchins. If this is the case and the urchins are now becoming more numerous in such districts, the increase will soon stop, and a balance between them and the sea-weed, such as is found on the remainder of the coast, will soon be established.

There are several reasons which lead me to believe that the sea-urchins will never be able to strip our coast of seaweed, and that if there is a decrease of seaweed in any district we must look for causes other than sea-urchins. In the first place an equilibrium between the sea-urchins and the seaweed must have been established some ages ago, because sea-urchins are among the most numerous of fossil animals and historic records show that they have always been abundant on our Atlantic coast. Thus Champlain mentions that urchins were common on Dochet's Island in 1604. In 1851 Dr. William Stimpson [9] collected on Grand Manan and describes the life on its shores as follows: 'The shores of Grand Manan are covered, in many parts, with such numbers of sea-urchins, that it is impossible to make a step without crushing one or more of them .... It would be interesting to ascertain what constitutes the common food of such a multitude of animals. I have seen a barren rock of several rods in extent, covered with Echini, upon which no other animal, nor any plant could be detected, which might serve them for food. I should mention, that when a fish is killed by the fisherman and thrown into the water, it becomes covered with Echini, who soon devour it.' If Dr. Stimpson had examined the intestinal contents of these urchins he would, in all probability, have found globular masses of sand which contained numbers of minute organisms. On page 716 of the report before mentioned, Verrill [6] describes the sea-urchin as 'Very

abundant in the Bay of Fundy, from low water to 109 fathoms, ... Fossil in the Post-pliocene of Portland, Maine, U.S. ; New Brunswick, Canada ; and Labrador.' These records show that sea-urchins have been abundant on our coast for many years, and if they are such enemies of seaweed, the seaweed would, in all likelihood have disappeared before man came to this continent.

In the next place there are only a few districts in which the seaweed is said to be decreasing. There are now localities where sea-urchins are so numerous that it would be hard to imagine them more abundant—where they are massed in heaps often obscuring the bottom—and yet in these very places seaweed is equally plentiful, great bunches being found in all suitable places. I have seen boulders covered with seaweed, and yet in the interspaces between the boulders the bottom was literally carpeted with urchins whose intestines contained seaweed alone. In case it might be suggested that the seaweed would soon begin to decrease in these localities, it may be remembered that from Dr. Stimpson's description sea-urchins were very abundant on Grand Manan in 1851—a half century ago—and although they have continued to be so until the present time, Grand Manan is not one of those places where seaweed is said to be decreasing.

In the third place, the sea-urchins do not live on exactly the same zone of the beach as the seaweed. The ordinary seaweed is most plentiful between tide-marks, beginning about half-tide and extending a little below the low tide mark. The sea-urchins, however, are not found above the low tide mark and are abundant in about half a fathom. As shown before a sea-urchin might move a considerable distance in the course of a tide, but as a rule they do not move very far. They certainly do not move up the beach as far as the seaweed extends, and thus a large part of the seaweed is really inaccessible to the urchins.

In the last place it must not be forgotten that there are probably nearly as many urchins living on surface sand as on seaweed. It is quite surprising the difference a few feet may make in the character of the food of these animals. In one case urchins living 15 feet from boulders covered with seaweed had not eaten any of it. At the same time other urchins within a yard of the same boulders had plenty of seaweed in their intestines. As a general statement I would say that any urchin, which at low water is 10 or 15 yards away from seaweed, will be found to have eaten very little of it.

In conclusion it may again be pointed out that sea-urchins can live without the large fucoid or laminarian seaweeds ; that there are localities now in which sea-urchins and large seaweeds are both abundant and have been so for years ; and that a great proportion of the seaweed on our coast is really inaccessible to the sea-urchins owing to their limited means of locomotion. There is no doubt that the myriads of sea-urchins on our coast do consume an immense quantity of seaweed in a year, but seaweed grows rapidly and thus its consumption by the urchins has been going on for ages. From the above considerations we may conclude that there is no danger of sea-urchins denuding our coast. Although my studies were not made in one of the districts where the seaweed is said to be decreasing, it seems to me, that if the seaweed really is diminishing we must look for other causes rather than the sea-urchins for its devastation.

REFERENCES.

[1] Ganong, W. F., 'The Echinodermata of New Brunswick,' Bulletin of the Natural History Society of New Brunswick, No. VII., p. 12, 1888.

[2] Sharpey, W. 'Echinodermata.' Todd's Cyclopædia of Anatomy and Physiology, Vol. II., p. 39, London, 1838.

[3] Butler, F. H., 'Echinodermata.' Encyclopædia Britannica, ninth edition, Vol. VII., p. 631, Edinburgh, 1877.

[4] Schmidt, Oscar, Brehm's Thierleben, zweite Auflage, p. 430, Leipzig, 1878.

[5] Dawson, J. W., 'The Food of the Common Sea-Urchin.' The American Naturalist, Vol. I., p. 124, 1867.

6 Verrill, A. E., 'Report upon the Invertebrate Animals of Vineyard Sound and the Adjacent Waters, with an Account of the Physical Characters of the Region.' Report of Commissioner of Fish and Fisheries, Washington, 1874.

7 Packard, A. S. 'Zoology.' Henry Holt & Co., N.Y., p. 199, 1893.

8 Schiemenz, Dr. Paulus, 'How do Starfishes open Oysters?' Translated from the German by E. J. Allan in Journal of the Marine Biological Association of the United Kingdom, Vol. IV., (N. S.) p. 366, 1895-97.

Stimpson. W. Proceedings of the Boston Society of Natural History, Vol. IV., p. 96, 1854.

VI

THE PAIRED FINS OF THE MACKEREL SHARK

BY PROFESSOR E. E. PRINCE, DOMINION COMMISSIONER OF FISHERIES,

AND

DR. A. H. MACKAY, SUPERINTENDANT OF EDUCATION FOR NOVA SCOTIA.

Preliminary Note by the Director, Prof. Prince.

In August, last year, a specimen of the Mackerel Shark (*Lamna cornubica*, Gmelin) was brought to the Biological Station, then at St. Andrews, N.B. Dr. A. H. MacKay was making a short stay at the Station and I suggested to him that the preparation and study of the skeleton of the paired fins, especially the pectoral fins, would form a compact subject which could be overtaken without involving labours too prolonged, and would afford matter of some morphological interest. Dr. MacKay, with much skill, made two most valuable preparations, and these with the drawings completed at the time, appeared to me to furnish a basis for a short paper on the subject of the paired piscine limbs.

With Dr. MacKay's consent I have combined his work and my own further studies on his preparations and drawings, and it is necessary only to add that apart from the general conclusions usually favoured by comparative anatomists to-day, the responsibility rests upon me for the interpretation of the skeletal elements set forth in the following brief report.

GENERAL CONSIDERATIONS.

The pectoral fins of *Lamna cornubica* are remarkable, even amongst the sharks, for their great development and powerful muscular and skeletal characters. Instead of the somewhat regular triangular form of fin as seen in *Squalus* (*Acanthias*), in *Catulus* (*Scyllium*), in *Scymnus*, or even in *Notidanus*, we find that while the fin is broad in transverse width, it is greatly deepened in longitudinal extent, and presents a prolonged lobate expanse, hanging far below the ventral contour of the trunk, and showing a correspondingly strengthened, and expanded cartilaginous support. In its elongated expanded character it recalls the pectoral limbs of the monstrous *Selache maxima*, or *Carcharinus lamia*. *Lamna*, like its congeners, is a surface swimmer, and its breast fins are in keeping with its pelagic mode of life.

On examining the skeleton of the pectoral fins as figured in Plates V and VI we find three regions defined, viz., a basal portion articulating, for the most part, with the shoulder girdle; a radial portion, made up of a series of jointed rods; and a marginal portion consisting of thickly massed horny fibres. The basal portion thus composed of a small number of cartilaginous elements, forms the basipterygium, the morphological nature of which has aroused much controversy. There is, however, a general agreement as to its constitution. As the late Professor Rolleston said,* 'the fore-limb consists typically in Elasmobranchii of three basal cartilages,—pro-, meso-, and meta-pterygium, articulating each with a facet on the shoulder-girdle: of one or two outer rows of cartilaginous rods known as radialia, followed by horny fin-rays.' Ontogenetically these basal elements and outer cartilaginous rods arise as a large flattened plate which breaks up into the series of cartilages found in the fin of the adult fish. From the phylogenetic

* Forms of Animal Life, 2nd Ed. Oxford 1888, p. 416.

point of view it is hardly necessary to point out that very diverse views are held respecting the significance of these cartilages and the process by which they assumed their present form and arrangement. Indeed, as Professor Wiedersheim has said,† "No other morphological problem has given rise, during the last twenty years, to such extensive researches, and to such varied solutions as the question of the origin of the paired limbs. Two very opposite views exist. According to one of these (Gegenbaur's view) the proximal parts of the extremities, that is, the pectoral and pelvic arches, are regarded as being derived from branchial arches, and the distal or free portions as metamorphosed fin rays. . . . . According to the other view (that of Dohrn), the origin of the paired limbs has nothing to do with the visceral skeleton : but, like the latter, they are to be looked upon as the localized remains in definite regions of the body (thoracic and pelvic regions) of a series of cartilaginous bars extending originally along the whole trunk, and having a metameric arrangement. In other words, just as each body-segment of an Annulate may be looked upon as being provided with a pair of limbs, so also was each primitive segment of the Vertebrate body ; recent researches seem to support this.' Professor Huxley adopted Gegenbaur's theory, though with grave modifications, and the theory of Dr. Anton Dohrn has been considerably transformed by the researches and suggestions of Mivart, F. M. Balfour, and J. K. Thatcher. Whatever be the mode of origin of the limbs of fishes they present in Plagiostomes, the Holocephali, and other primitive forms, certain structural features in common, and in most of them the tripartite nature of the basal cartilages is clearly seen. One or more may abort or may be shifted from direct articulation with the pectoral bar ; but one (according to Gegenbaur the metapterygium ; according to Huxley the mesopterygium) is constant, and through it the theoretical axial line of the limb must be drawn. It is clear that an element of uncertainty must often attach to the determination of these basal cartilages, but the same is true of even so familiar an extremity as the frog's *manus*, for the middle element of the proximal row of *ossa carpalia* is named by Ecker the *os lunatum*, whereas Dugès did not hesitate to pronounce it the *os naviculare*.

But, as already stated, there is a uniformity in the basal elements present in these primitive forms of the locomotor limb, and the comparison of a large number of diverse types, illustrated in the existing species of Plagiostomes, Ganoids, &c , affords a guide to their accurate interpretation.

SKELETON OF THE FIN.

The fin of *Lamna* is in many respects peculiarly interesting. On comparing the number, form and disposition of the skeletal elements, with those seen in the fins of other primitive types of fishes, we observe a number of noteworthy morphological features. In the first place the basal pieces (Plate V., fig. 1, pro. mesop. metap.) are not lengthened and expanded as in *Acanthias* (Plate VII., fig. 4) or *Scyllium* (Plate VII., fig. 3) but form a row of compact shortened elements, of which the metapterygium (metap.) alone is somewhat elongated, though in the lateral direction, not in the longitudinal as seen in the fins of the species just referred to. Now the whole fin expansion is enormously lengthened longitudinally, and this shortening in the length of the basal pieces results in the exaggerated enlargement of the remaining part of the cartilaginous skeleton. The rows of jointed rays, whose extent is so much reduced in *Acanthias*, in *Heptanchus* (Plate VII., fig. 5) though so primitive a form, and in *Chimaera* and *Polyodon* (Plate VII., figs. 6 and 8) are in *Lamna* so long and cover transversely so large a space that they are almost coterminous with the entire outer limits of this extensive lobate paddle. Upon the outer portions of the cartilaginous expanse the thick provision of slender horny rays forms a dense thatch, and extends only for a short distance beyond the distal margin of the radial elements (Plates V. and VI., figs. 1 and 2,h.). Fully seven-eighths of the fin-expansion are occupied by these jointed rays, the basal plates covering less than one-eighth of the surface of the fin, though in most Selachian fins, they cover proportionally three or four times that area. There has been reduction in the length of

† Elements of the Comp. Anat. of Vertebrates, trans. by W. N. Parker, London, 1866, p. 86.

the basipterygial cartilages no doubt, but the disproportion is due no less to the large development of the long cartilaginous rays.

The cartilaginous fin-plate, as stated on a prior page, breaks up distally into rod-like rays which by subsequent dichotomous division become extremely long and slender in *Lamna*. At least six rays in the fin of the right side (Plate VI., fig. 2) have undergone partial dichotomy distally, and in the left fin (Plate V., fig. 1) two rays show each at their outer end a division into three, but the division extends merely for a short distance.

The stout cylindrical piece at the upper anterior margin of the fin is the propterygium. It has a conical nodular form, the apex being segmented into two or more distal elements, recalling the condition in *Acanthias* (Plate VII, fig. 4), and it articulates with the pectoral arch by a concave facet, being held in place by strands of dense fibrous tissue. The small rod-like cartilage on the outer margin of the propterygium (Plate VI., fig. 2*a*) is probably merely a migrating rudimentary ray, (in the left fin this rod consists of three segments, (Plate VI., fig. 1*a*) the rays pushing their way in many species into the basal series and, as in *Torpedo* and *Trygon*, separating the propterygium and the mesopterygium, or, as in *Raia*, separating the mesopterygium and the metapterygium (Plate VII., fig. 9). Two such secondary *basalia* are present in *Myliobates*, leading some anatomists to regard the mesopterygium as split into two. Closely articulating with the propterygium is the somewhat regular quadrate mesopterygium (mesop.), a flattened plate of cartilage in contrast to the stout cylindrical form of its more external neighbour (pro.) This flat plate articulates by its two shorter opposite sides, on the one hand with the propterygium, and on the other with the metapterygium (Plates V. and VI., figs. 1 and 2). To its outer margin six fin-rays may be attached, the first joints being irregular nodules with which more is distally articulated in the right fin one larger cartilage, in shape like an inverted L, and formed by the confluence of two rays at their base. Irregularity in the division of the proximal portion of the first two mesopterygial rays is frequent, as in *Acanthias* (Plate VII, fig. 4) and in *Cestracion* (Plate VII, fig. 7).

In almost all the forms of pectoral fin referred to in this paper the metapterygium (metap.) presents the character of a large elongated plate articulating with the mesopterygium (mesop.) by its anterior margin, and at its other extremity bearing a series of irregular basal elements. If these nodules in *Lamna*. one of which has the form rather of a flattened obquadrate plate, be simply parts segmented off from the metapterygium, they would correspond to the two pieces shown in Wiedersheim's figure of the fin of *Heptanchus* (Plate VII., fig. 5 *x. y.*). There is more reason, however, to regard the four nodules (*m.m.m.m.*) at any rate as the detached proximal joints of the six adjacent rays like the similar nodules at the anterior end of the mesopterygium (Plate VI, fig. 2 *n. n.*). The intruding triangular fragment of cartilage (*o.*) may indeed be a fifth displaced nodule of the series and the oblong bit (*m.*) on the left of the series may represent two such coalesced terminal nodules. There is every reason to regard the three elements (*metap. o.* and *q.*) as metapterygial, and the metapterygium thus bears a total of no less than twenty-two fin-rays, the mesopterygium carries only six, and the propterygium one or, at the most, two rays. The distal termination of the 19th (or it may be the 20th) ray (Plate VI., fig. 2) shows a peculiar bifurcation, so that it ends not in one or two digitiform points but in no less than four, three of them distinctly dactyliform. The nodule marked *Z* may be the displaced terminal segment of 19, as 18 may be the similar displaced piece froi the 18th ray. The remaining eleven rays are all markedly digitiform excepting the 25th, 26th, 27th and 30th, which have no terminal acuminate nodule such as the others possess. Similar distal segments are seen in the fin-rays of *Scyllium*, *Heptanchus* and *Chimæra* (Pl. VII., figs. 3, 5 and 6), though the reduction in the cartilaginous skeleton of the fin of *Scyllium* is such that the hexagonal, or rather, somewhat geometrical polygonal nodules, around the margin of the series of rays, may represent not the digitiform elements of *Lamna* or *Chimæra*, but the last two segments. The segmentation of the rays in *Lamna* is not wholly regular, though three rod-like portions are segmented off in most, and there is, on the whole, a regular uniformity in this feature. Some rays exhibit an additional terminal nodule, and a number exhibit partial longitudinal and false transverse segmentation. The small cartilaginous rod lying just outside the propterygium in the right fin(Pl. VI., fig. 2, *a.*) and the pair of two-jointed rods occupying a parallel position in the left fin (Pl. V., fig. 1, *a.*) are, as already indicated

probably migrating rays moving up towards the girdle. 'In the effectual discharge of the function of the fish's fin, increase of breadth is needed: and this increase of surface is obtained by the gradual approximation of more and more lateral elements of the archipterygium to the shoulder-girdle* was a characteristically apt observation of the late Professor Huxley.'

This brief description of the pectoral fins of *Lamna*, and the comparison made between its skeletal structure, and that of certain other primitive fins of morphological interest, it need hardly be pointed out, amply substantiates the point urged at the commencement of this paper, viz:—the modification of the basal and radial cartilages for the purpose of increasing the breadth and depth of the fin, and thus increasing the propelling capabilities of the limb. The shortening in longitudinal direction of the basipterygium and its increase in compactness and strength, is accompanied by an extraordinary lengthening of the free part of the fin, the slender cartilaginous rays being, as before pointed out, remarkably long.

Many interesting theoretical suggestions arise in the study of such a pectoral fin as that of *Lamna*, but the limits of this report preclude any generalizations involving lengthy references to the extensive existing literature, English and foreign, upon the morphology of the paired fins in fishes.

---

* Huxley "on *Ceratodus forsteri*" Proc. Zool. Soc., Jan., 1876, p. 55.

EXPLANATION OF PLATES.

PLATE V.

FIG. 1. Left pectoral fin of *Lamna cornubica* with muscles and integument removed. About one-third natural size.

PLATE VI.

FIG. 2. Right pectoral fin of *Lamna cornubica*. About one-third natural size.

PLATE VII.

FIG. 3. Right pectoral fin of *Scyllium* after A. Milnes Marshall.
FIG. 4. " " *Acanthias* after Gegenbaur.
FIG. 5. " " *Heptanchus* after Wiedersheim.
FIG. 6. " " *Chimæra* after Bashford Dean.
FIG. 7. " " *Cestracion* after Huxley.
FIG. 8. " " *Polyodon* after Huxley.
FIG. 9. " " *Raia radiata* after A. T. Masterman.
Pro. Propterygium.
Mesop. Mesopterygium.
Metap. Metapterygium.
a. Displaced anterior ray.
h. Horny fin-fibres.
m. n. o. Probable separated nodules of adjacent rays.
Probable separated nodule from ray termination.
y. Main fin-ray of Metapterygium (according to Wiedersheim).

Plate V.

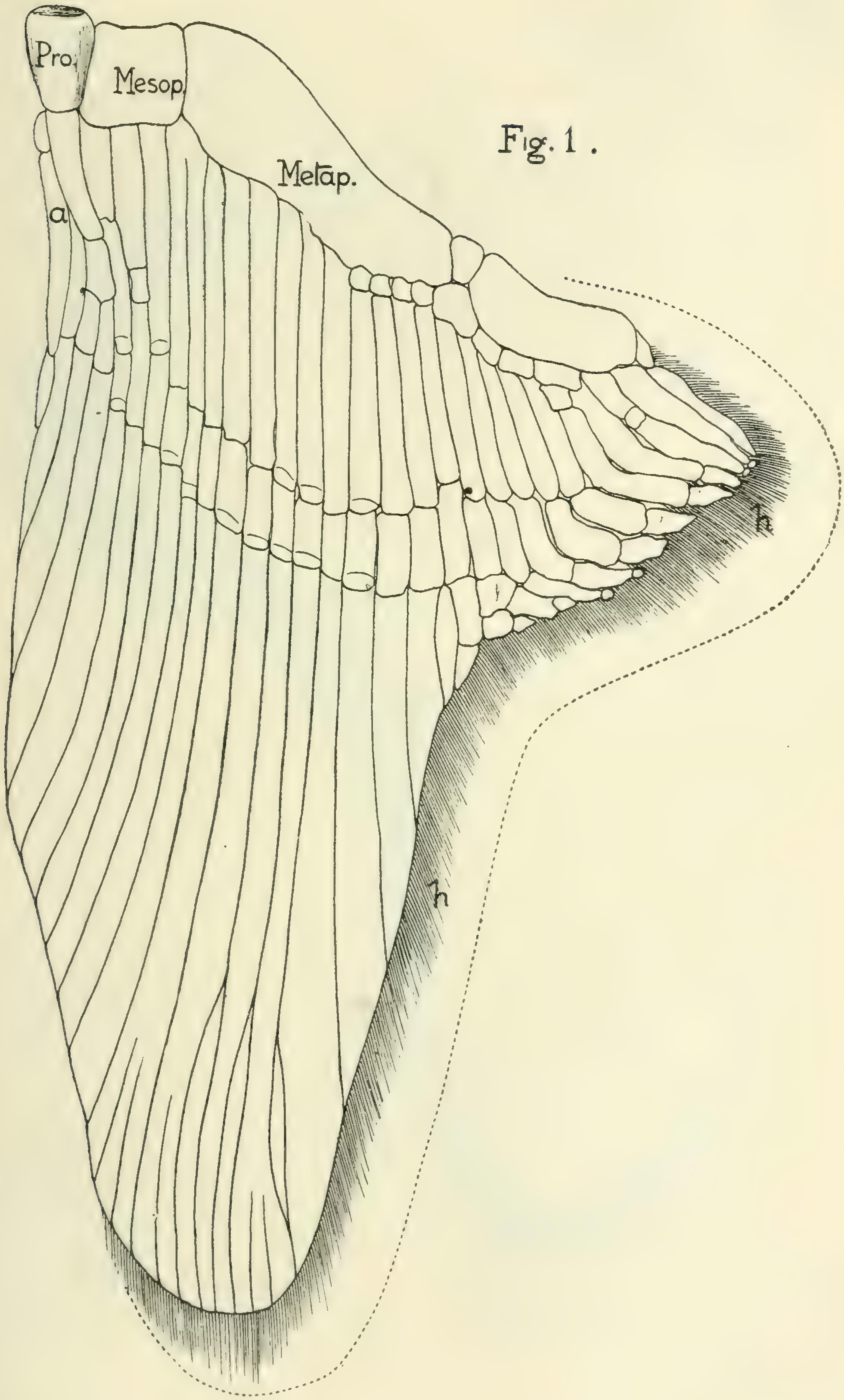


Fig. 1.

Plate VI.

Fig. 2.

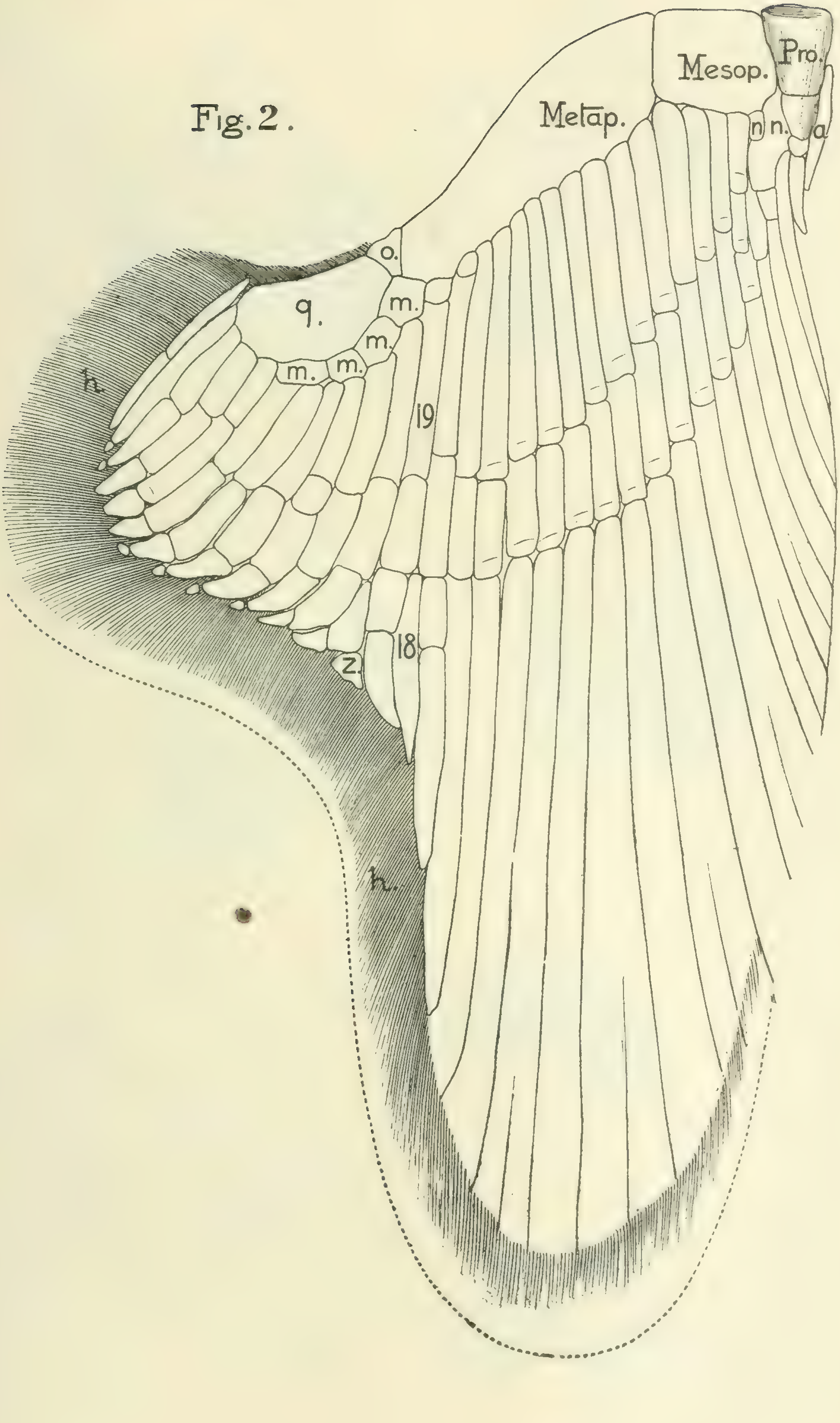


Plate VII.

Fig 3.

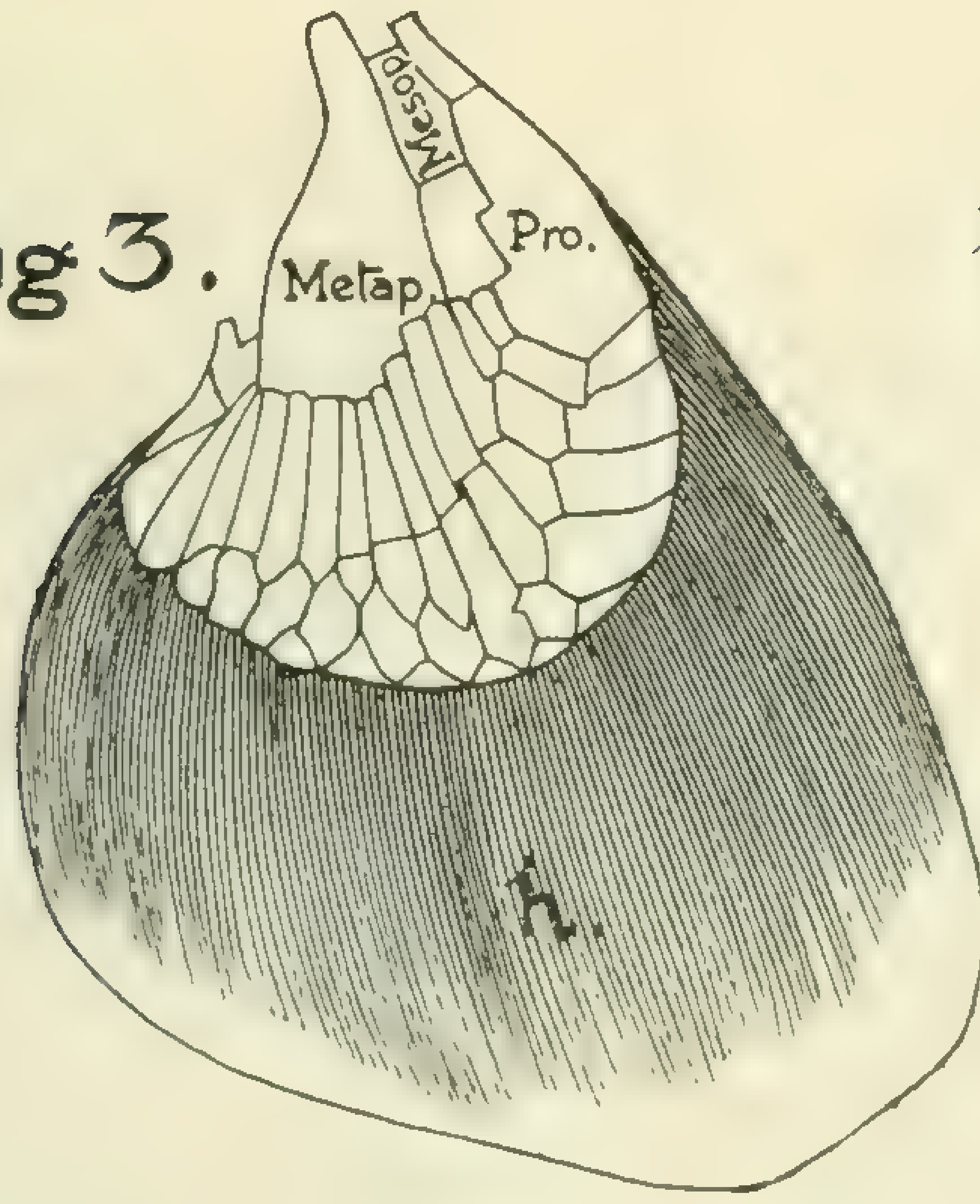


Fig 4.

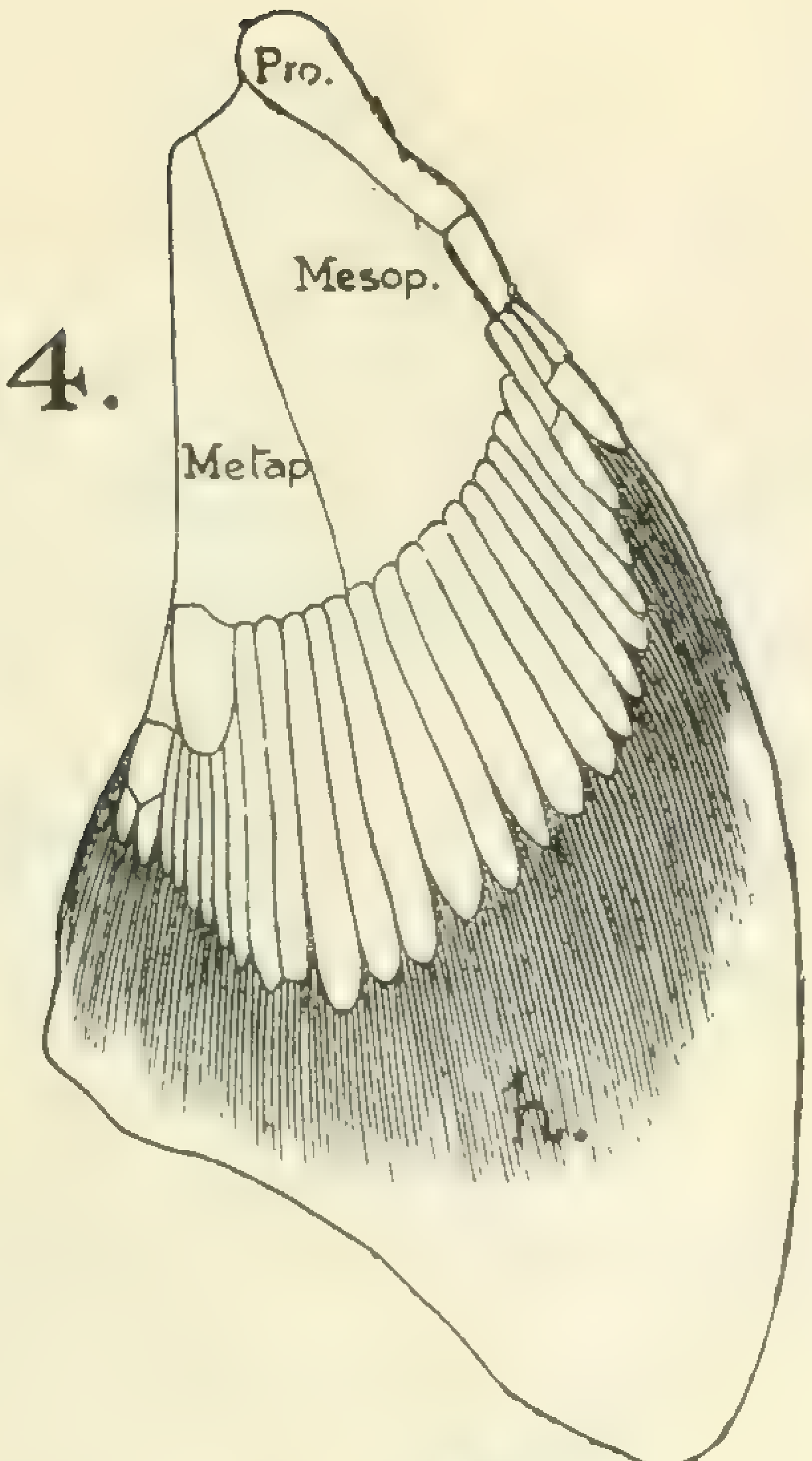


Fig 5.

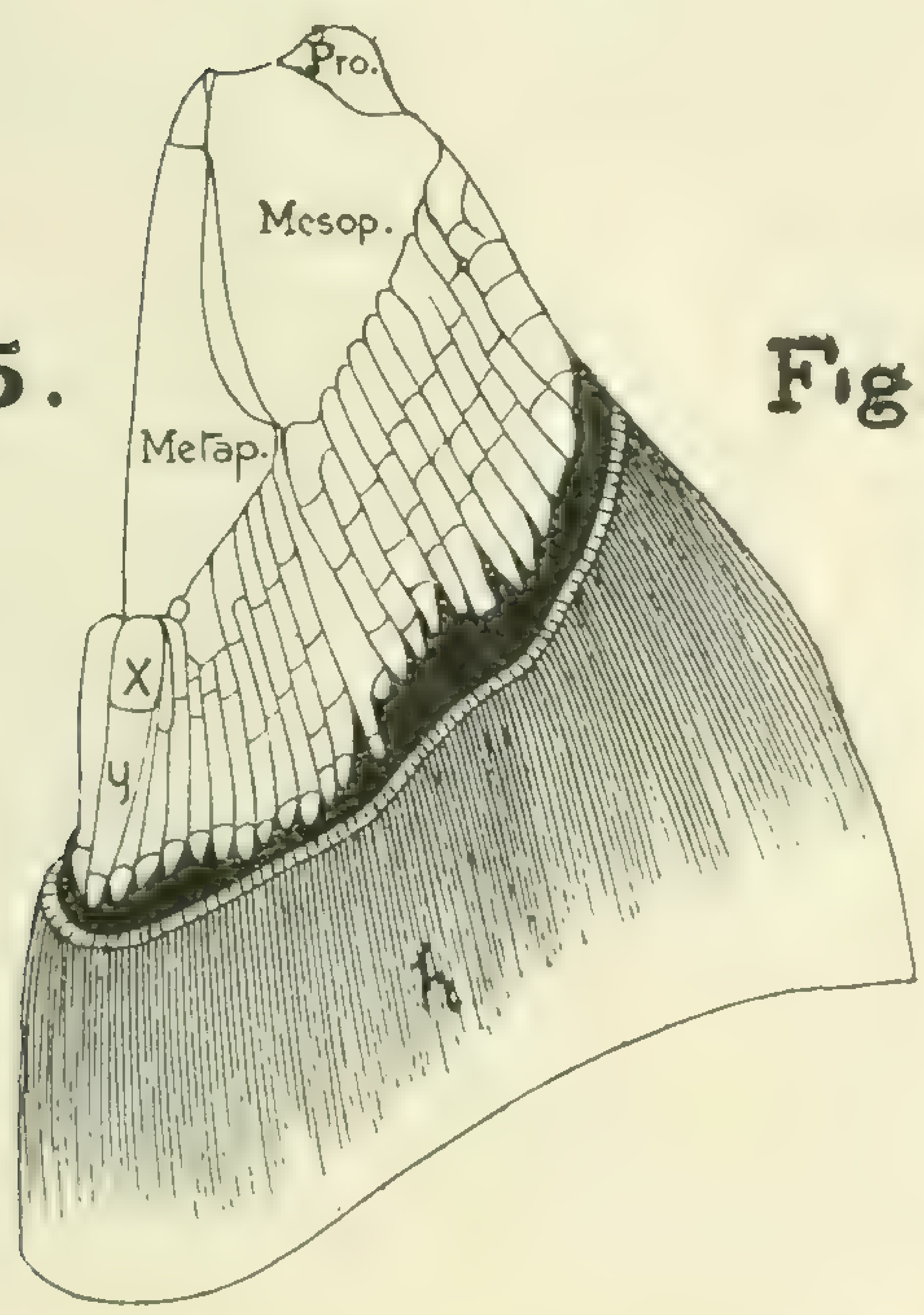


Fig 6.

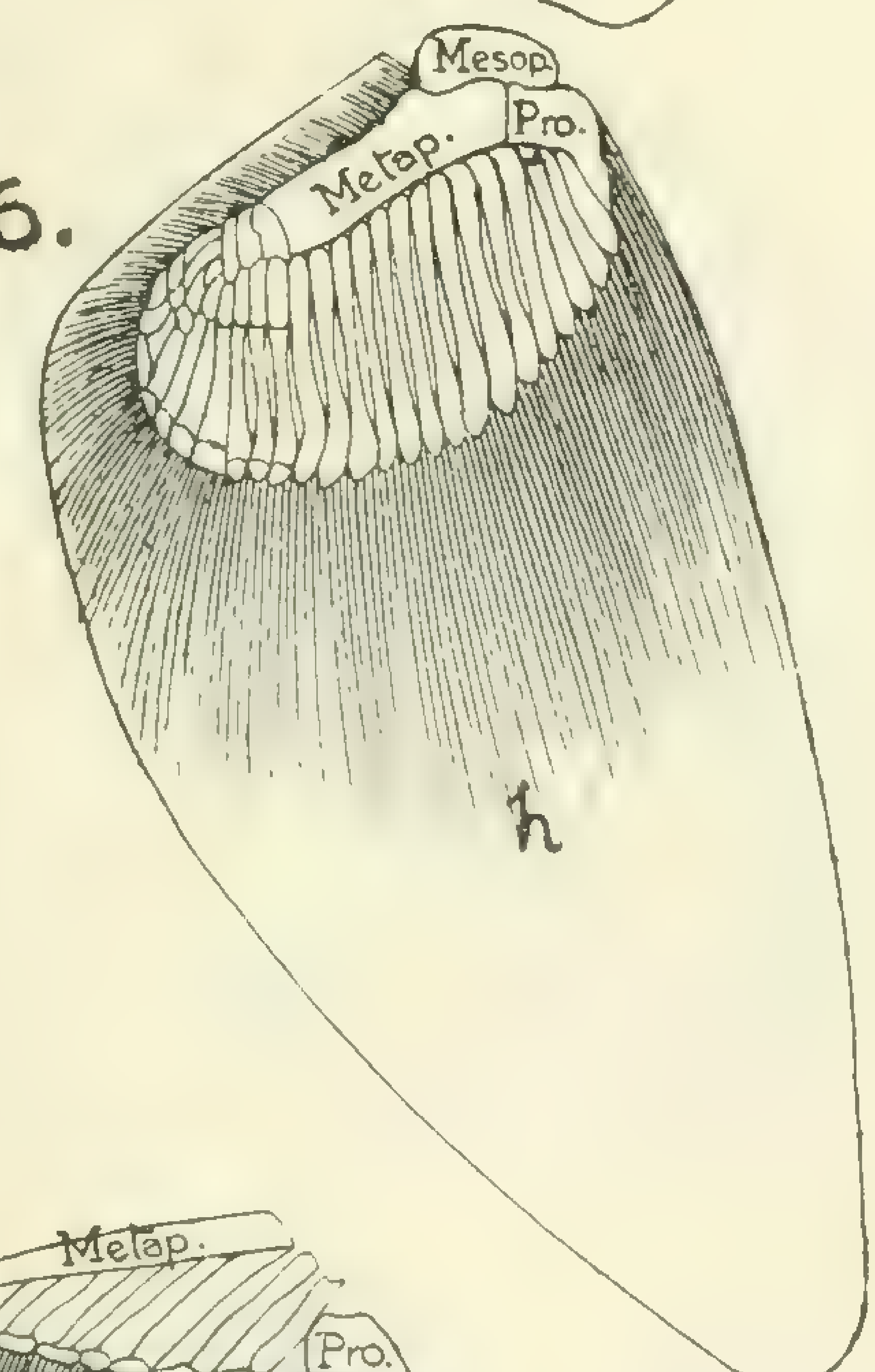


Fig 7.

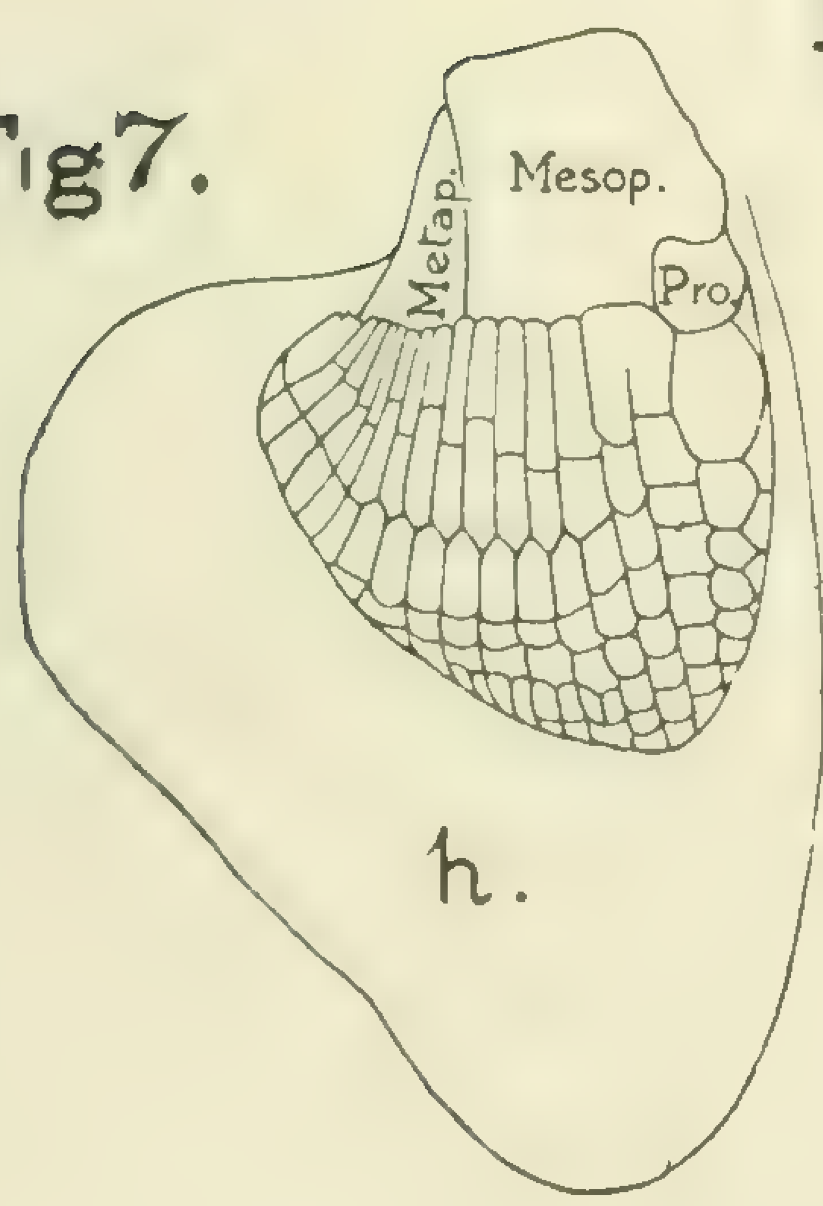
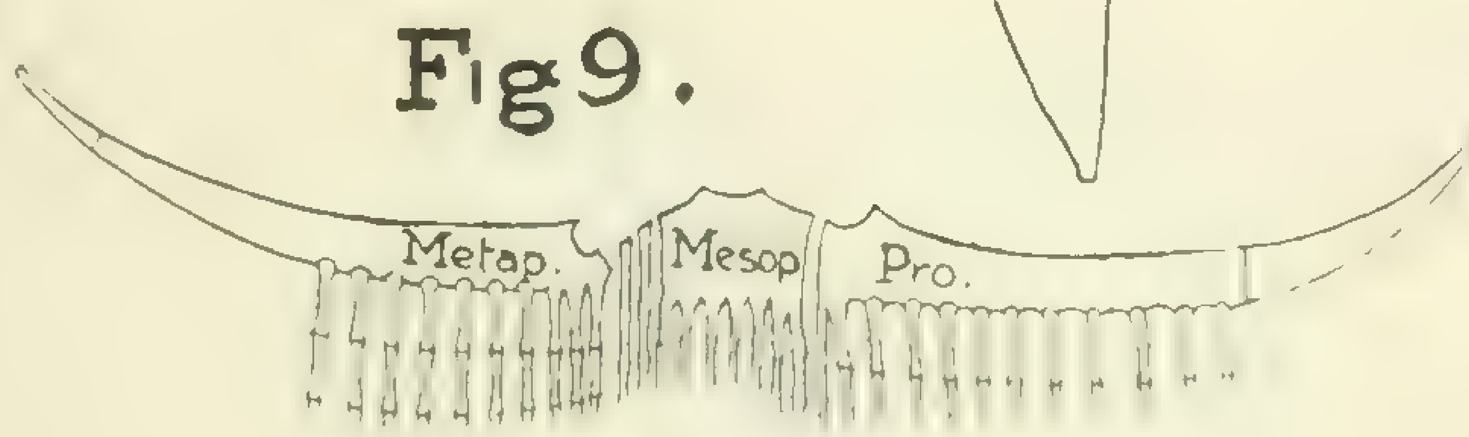


Fig 8

Fig 9.



V I

REPORT ON THE SARDINE INDUSTRY IN RELATION TO THE CANADIAN HERRING FISHERIES.

BY B. ARTHUR BENSLEY, B.A., &c., LATE FELLOW IN BIOLOGY, UNIVERSITY OF TORONTO, AND OF THE COLUMBIA UNIVERSITY, NEW YORK, U.S.A.

The present investigation was undertaken at the suggestion of the Director of the Marine Biological Station of Canada, Professor Prince, Dominion Commissioner of Fisheries, the purpose in view being to determine whether or not the noticeable decline in the herring fisheries of the Bay of Fundy, and the western Nova Scotia coast, is attributable to the operation of the so-called sardine weirs, or brush traps, especially off the New Brunswick shores. In these weirs, which are really wicker-work inclosures, vast numbers of young fish, largely belonging to the Family Clupeidæ, are annually captured. Between seven and eight hundred of these traps are fished every season under licenses issued by the Dominion Government, and on some of the West Isles off Passamaquoddy Bay limited parts of the shore are thickly studded with these fish-weirs. It is alleged by fishermen in the waters further north, especially in St. John County, N.B., that there has been a serious decrease in the supply of full-grown herring, indeed that certain schools, which provided important fisheries in former years, have totally disappeared. In Digby County, N.S., a similar allegation is made. 'How can you expect the herring in the upper part of the Bay of Fundy and in the Annapolis Basin and St. Mary's Bay to continue plentiful, if they are destroyed and exterminated in the New Brunswick sardine weirs before reaching maturity?' wrote a prominent authority in Nova Scotia not long ago. Professor Prince in a special report to the Honourable the Minister of Marine and Fisheries in 1895 referred to this alleged injury in the following terms (28th Annual Report of the Department of Marine and Fisheries, pp. xxxi. and xxxii.) :—

'It is doubtful whether any fishery can withstand for long so serious a drain upon immature individuals. No doubt the hardy nature of the herring's eggs and fry help to keep up the numbers; but other species of fish in the sea would succumb were specimens that had never spawned captured in such vast quantities. All efforts to diminish the supply of herring here, as in Great Britain, have had apparently little effect. Some authorities have explained the non-appearance of the large winter herring in the Bay of Fundy, as for example in 1891, by the continued destruction of small fish for sardine purposes. The run of sardines also has shown at times a very marked diminution, but not more than may be attributed to the ordinary fluctuations of such a fishery. Indeed, it is a striking fact that in the years 1890-91 these small fishes were more abundant than they had been for twenty years previously.

It cannot, therefore, be said that the capture annually of vast quantities of immature fish has had any serious effects. The possibility is suggested that a considerable proportion of these small fishes may belong to other Clupeoids, though this is contrary to the common opinion of those engaged in the sardine industry.

It is still an open question, therefore, whether this destruction, on a large and increasing scale is or is not calculated ultimately to endanger the supply of large herring. If schools of young are killed off before they have reached the spawning age, the general catch of the future must ere long be affected.'

The matter is one of great importance, as, on the one hand, the so-called 'sardine' fishermen, who form a considerable body on the Charlotte County shores, derive a large part of their income from the weir returns, and, it may be added, the United States sardine industry centred at Eastport and Lubeck, in the State of Maine, but also carried on at Milbridge, Jonesport and Machiasport, depends largely upon supplies of fish from the Canadian fishermen. As Professor Prince, in his report referred to above, says (pp. xxvi. and xxvii.): 'The United States canneries could not carry on their operations for a single day but for the ample supplies of fish obtained from our waters, and the sardine industry, so far as our fishermen are concerned, is confined to the capture of the fresh fish and their disposal to the Maine canneries. At least ninety-five per cent of the so-called United States sardines are caught by our fishermen on Canadian shores, and these are, for the most part, packed in Eastport, Lubeck and other small towns in the State of Maine.'

Of such importance is the supply of these small fishes that a large proportion of the population on the Maine coast, as well as the body of Canadian fishermen who pursue their calling amongst the islands of the Bay of Fundy and neighbouring waters, may be said to be largely dependent upon the sardine industry. A failure in the supply of these fishes would mean disaster to those engaged in cleaning, curing and packing, and who have capital invested in the canneries, and would, without doubt, seriously affect the Canadian fishermen who find lucrative employment in the capture of the sardines. That the small fish, known as sardines in these waters, were abundant on the shores of Charlotte County, N.B., was long known to our fishermen, but their value was not appreciated, and the only use to which they were turned was that of conversion into manure for the purpose of fertilizing the land.

On the other hand a considerable number of N.B. and N.S. fishermen claim that they have suffered injury from this alleged capture of small fish, and as the matter had never been systematically looked into, it was my object to examine as far as possible the catches from certain weirs, and to ascertain what species of fish were really captured for the purposes of the sardine canning industry.

With this end in view, it was desirable to ascertain, in the first place, the character of the fish used as sardines, and, in the second, the extent to which these and other clupeoid fishes are affected by the operation of the brush weirs. Accordingly samples of the catch were obtained from fishermen in charge of the weirs, at different times during the month of August, and under different conditions. All of the fish examined were taken from weirs in the immediate vicinity of the Canadian Marine Station then located at St. Andrews, New Brunswick. Below is given a summary of the results obtained.

On August 1 an average series of 31 specimens from Malloch's weir, off Indian Point showed the following composition:—

Species.	No. of Specimens.	Size (length).
		inches.
Clupea harengus, L. (Common herring)	29	5½—7
Pomolobus pseudoharengus, Wilson (Alewife)	1	8¼
Microgadus tomcod, Walbaum? (Tom-cod, Frost-fish)	1	11

The query placed opposite the Tom-cod indicates that in certain important diagnostic features this specimen did not correspond with the description of *Microgadus tom-cod* in Professor D. S. Jordan's Manual of the Vertebrate Animals of the Northern United States, 5th edition, Chicago, in respect, for example, to the number of rays in the three

divisions of the dorsal fin (14–20–20) and in the relation of the eye to the head (6) as given in the work mentioned (p. 163).

On August 4 a lot of 286 specimens from Quinn's weir was made up as follows :—

Species.	Number of Specimens.	Size.
Clupea harengus, L.	285	263, 5—7 in. ; 22, 8—9½ in.
Osmerus mordax, Mitchill	1	10 in.

On August 5 a sample was received from Miller's weir on the south side of Navy Island near St. Andrews, the fishermen having been instructed to bring specimens of all of the varieties of fish taken. This lot was made up as follows :—

Species.	Number of Specimens.	Size.
Melanogrammus aeglefinus, L. (Common haddock)	1	11 in.
Microgadus tom-cod, Walb.	1	13 in.
Osmerus mordax, Mitchill	2	10—12 in.
Gadus callarias, L. (Codfish)	2	11—13 in.
Pollachius virens, L. (Pollack)	4	8—11 in.
Clupea harengus, L	179	3, 11—12 in.; 176, 4¾—7 in.

On August 9 a small sample of the catch, consisting of five fish, was received from Malloch's weir, as follows :—

Species.	Number of Specimens.	Size.
Scomber scombrus, (Mackerel)	1	14 in.
Clupea, sp. ?	2	$7\frac{5}{16}$—8¼ in.
Pomolobus pseudoharengus	1	8⅜ in.
Clupea harengus	1	10 in.

I may remark that the specimens marked with a '?' corresponded to the description of *C. aestivalis* in Jordan's Manual, 5th ed., p. 72, except in the relation of the head to the length ; (Head 4), a detail probably subject to no little variation.

On August 14 seven especially large specimens of *C. harengus* were received from Quinn's weir. These ranged from 11 to 14 inches in length, and on dissection I found that the ova in the females were almost mature.

On August 15 a sample was received from Malloch's weir which had been taken on a ni:ht tide. This was made up entirely of *C. harengus*, of which there were 211 ranging in size from 5 to 7 inches, and four ranging from 8 to 10 inches.

On August 26 a small selection consisting of five fish was received from Malloch's weir, composed as follows :—

Species.	No. of Specimens.	Size.
		inches.
Clupea sp.?	3	8⅛—9½
Pomolobus pseudoharengus, Wilson	1	9
Rhombus triacanthus, Peck (Dollar-fish)	1	5¾

It is apparent from the above facts, limited though they undoubtedly were, that the bulk of the catch of the brush weirs consist of the 5 to 7 inch young of the common herring (*Clupea harengus*), and that these provide the material for the sardine industry. The young of other clupeoid fishes do not appear to be affected, if one may judge by the average selections sent to the Biological Station, by the operation of the weirs and the adults of all only slightly. Further study is necessary, however, before a final decision could be finally rendered on this point, as there may be a vaiiation in different seasons. A more lengthy investigation extending over several seasons would be more conclusive. As noticed above, all the specimens examined were taken in the immediate vicinity of St. Andrews and during the month of August alone, and it may be possible, therefore, that the character of the catch may vary considerably at different points on the coast and at different periods of the sardine season. It is clear, in the case of the common herring, that the removal of such enormous numbers of the young in the sardine industry must be a very considerable drain on the supply however rapid the rate of increase may be. Whether this is the essential factor in the decline of the herring fishery alleged to have occurred in certain parts of the Bay of Fundy must remain doubtful, however, until adequate causes of decline can be assigned in the case of other clupeoid fishes.

An impression is stated to have, at one time, prevailed that the small fish used as sardines, are not the young of any larger species, but a diminutive kind of herring, which never exceeds a size of nine or ten inches.

The true sardine has, of course, never yet been recorded on our Atlantic coast, the so-called sardine in Florida being really an Atherine or kind of 'Silversides' scientifically known as *Atherina stipes* (*laticeps*). On the Pacific coast, moreover a small Clupeoid occurs, viz. : *Clupanodon caeruleus*, Girard, usually known as the Californian sardine. The anchovy (*Engraulis mordax*, Girard) also occurs and is canned in the United States under the name of sardine ; but in British Columbia neither of these fishes has been turned to commercial account.

The growth of the Maine sardine industry has been remarkable especially in view of the fact that the major part of the raw material comes from our Canadian waters. From 1875 to 1880 it is stated (C. H. Stevenson, Bullet. U. S. Fish Commiss. XVIII., 1898, p. 526) that there were only five sardine canneries in Maine ; but in 1880 the number rose to eighteen. In 1886 twenty-seven more establishments began operations. This number (45) fell in 1889 to thirty-seven ; but in 1892 increased to forty-six, while in 1898 there were no less than sixty-two of these canneries putting up so-called sardines. The average value is stated by Mr. Stevenson, in the report above referred to, as $2,000,000 per annum ; but in 1898 the value rose to $2,727,781, and in 1899 the New York *Fishing Gazette* estimated it to be not less than $3,000,000, the factories being chiefly confined to the towns of Eastport and Lubeck, which practically maintain their existence as flourishing business centres through this one industry.